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ORIGINAL ARTICLES.

I.—On Aggregate Deposits, and their Relations to Zones.

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[A paper read at the meeting of the British Association in September, 1898.]

GEOLOGICAL time, like all other kinds of time, can only be measured by the succession of events. If the events considered are constant in their recurrence and uniform in their nature, their *number* will afford the means of measuring the *length* of time. Thus the oscillations of a given pendulum, the rotation of the earth on its axis, and its revolution round the sun are sufficiently constant and uniform to afford a basis for our seconds, days, and years. Of such uniform and constantly recurring events geology affords no examples by which we could measure the length of geological time.

If, on the other hand, we consider a number of consecutive events as terms of a series, we obtain a scale by which to fix the epoch or moment of occurrence of any other event. The terms of this series may be all alike, as the years of a calendar; or they may be recurrent, like morning, noon, and night; or all different, as the succession of monarchs on a throne. Only in the first of these cases can we expect the scale to be of universal application; in the others we know that the morning at one place may be noon at another, and night at a third; while the dynastic succession in one country has no relation to that in another. Now geology supplies us with time-scale events of the two latter kinds only, and we cannot, therefore, expect that the chronology founded on them shall be of universal application—though the wider the application the better the chronology.

The events the succession of which has been applied to establish our geological chronology have been of two kinds—(1) the deposition of strata; (2) the development of the fauna, or in some cases the flora. The use of the former is the stratigraphical, that of the latter is the palæontological method. It would be very wrong, in my opinion, to put these two methods into antagonism with each other, and to argue in favour of one or of the other: they ought never to be divorced. It is as unscientific and misleading to say that the nature of the deposit is of no consequence as it would be to disregard

the specific character of the fossils. There are, moreover, cases in which one method or the other is the only one available, and therefore a widely applicable chronology must be founded upon both. It is the object of this paper to clear away a difficulty that sometimes arises in harmonizing the two methods.

Every species of fossil, considered as an inhabitant of the various parts of the earth to which it at any time extends, has a definite period of existence; and the same is true of every group of allied species, such as used to go in former times under one specific name; but in this case the range in space and time is greater. It follows from this that the epoch of every fossiliferous deposit must not only lie within the period of every fossil it contains, but also within that part where all the periods overlap. The deposit is like a document containing the signatures of numerous individuals, born at different dates and having different lengths of life; it must have been drawn up during the time that they were all alive together.

It was on this principle, which regards the whole of a fauna of a bed, that the classification of strata by zones was first established by Oppel. Unfortunately this principle of assemblages does not lend itself well to nomenclature, and for the purpose of naming the zone some particular fossil had to be selected. Such a fossil should be an abundant one, restricted as to range in time, but little restricted as to range in space. The selection, however, is arbitrary and may be unsuitable, but to the true student of zones it is a matter of comparative indifference; the zonal assemblage of fossils can be recognized without the presence of the particular name-giving fossil.

Amongst the Jurassic rocks, for the study of which the method of zones was first introduced, the greater number of name-giving fossils have been selected from the ammonites, which to a large extent best fulfil the necessary conditions; and this has apparently led in more recent years to an almost exclusive study of these types for the purposes of correlation, and to the practical assumption that the zone and the zone-naming fossil are strictly coterminous. Theoretically the life-history of a species is divided into three parts—its rise, culmination, and decline; or, as they are technically called, the epacme, acme, and paracme—and the zone is supposed to be the deposit formed during the acme. Practically, however, it is seldom possible to trace these three periods, and the presence or absence of the ammonite is all that can be stated. Thus the original idea of the zone is entirely altered. It is characterized no longer by an assemblage of fossils of all classes, each having its own range in time and each contributing to our estimate of age, but by the range of a single ammonite.

So long as the original idea of a zone was held, the occurrence of two of the name-giving fossils in the same bed caused no trouble beyond the suspicion that perhaps the fossil to be used for the name might have been better selected, but under the new idea such a combination is contrary to the practical assumption on which it rests. It becomes, therefore, incumbent on those who make this assumption to show that the combination of two or more zonal

ammonites in one bed is apparent only, and this they attempt to do by asserting that a careful search will show that these fossils occur in their proper position in different portions even of this single band, the older type being found near the bottom and the younger near the top. Theoretically this might be the case. There is no minimum thickness of a zone except that dependent on the fossils it has to contain to be a zone at all, and even in a uniform bed the fossils *might* be arranged in parallel layers one over the other in their proper order as ascertained elsewhere. Without being acquainted with the strata of all the world one is not in a position to say that this never actually occurs, but personally I have never seen an instance in which a careful attention to the lithology would not enable us to indicate a line of separation, however obscure, between the substance enclosing one fauna and that enclosing another, when both are of the ordinary character of more or less tranquil deposit.

The beds, however, which are claimed as multizonal, in all the cases which I have noticed, possess a peculiar character which removes them from the usual category of deposits, and which it is the object of this paper to point out.

The true value of zones is best observed and appreciated in those massive deposits, such as the Lias, the Oxford Clay, and the Chalk, which are disturbed by no episodes, and which do not vary in facies, but whose formation has been continuous through the life-history periods of several fossil species. The fossils in these deposits are found imbedded in what may be called their natural position, that is, they have been buried as they fell to the bottom, or died there, each being covered by subsequent portions of the deposit before their successors were buried above them. All the species that lived and died together lie on one surface in the rock, every portion of which has in fact formed the sea-bottom at successive times. This is well known to fossil collectors, who, finding some desired form in one place, can find others like it by following accurately the line of stratification. In this way every millimetre in the thickness of the rock represents the successive soft sea-bottoms. The multizonal bands are entirely different from this. The fossils in them do not lie in a natural position, but often stand on end; they are not arranged in horizontal bands, but are confusedly mixed together or huddled up in heaps; amongst them there are often broken fragments, often of a *remanié* character, and sometimes of considerable size. Now, according to the theory that considers these multizonal bands as the attenuated representatives of massive deposits elsewhere, the deposition here must have been very slow; but the irregular arrangement, the mixed character of the fossils, and the size of the fragments show that, instead of being very slow, the formation of the deposit must have been very rapid—indeed, tumultuous. The material can only have been brought to its present position by strong currents carrying it along horizontally.

I propose to assign to deposits having these characters the special term AGGREGATES. Although this is proposed in connection with multizonal bands, and is, indeed, intended to suggest how fossils of

different periods may have been brought together, it is not necessary that an aggregate should contain fossils of more than one epoch, the etymology of the word connoting only the assemblage of materials that have been moved horizontally, like a flock of sheep, over the surface of the ground. I would also propose to distinguish by name the two classes of fossils preserved, as noted above, in different ways. The ordinary fossils which are buried where the animals died or fell to the bottom, we may call *autochthonous*; and those which have been drifted to their final resting-place by currents, *heterochthonous*. The shells which lie scattered on the sands by any seashore, when buried will produce autochthonous fossils, while the heaps of dead shells which are crowded together in certain localities, as the island of Herm, Morte Bay, and the estuary of the Thames, will produce heterochthonous fossils.[1]

From these definitions it follows that the fossils of an aggregate are essentially heterochthonous, though they may be accompanied by others which are practically autochthonous. It follows also that we may expect aggregates to be exceptionally fossiliferous, and conversely, when we hear of a bed being exceptionally fossiliferous we may suspect that it is likely to be of an aggregate character. But the most essential point to notice is, that when a bed is an aggregate the fossils in it have not been buried *pari passu* with the formation of the deposit, but existed before it commenced to be formed, so that we have no proof that the fossils it contains belong to the same age as the deposit itself, or that they belong to any single age. This would, of course, be self-evident if the fossils were recognized as *remaniés*. But it is not necessary that a heterochthonous fossil should have been previously buried in a deposit which became sufficiently hard to make a pebble; it may have lain on the sea-floor, even for geological ages, uncovered by deposit, or so slightly covered that it is washed out again by the current when this begins to flow, and is finally buried in the finer mud brought by this current. The extinct bones and teeth which have been dredged up from the bottom of the Atlantic prove the possibility of this.

These extinct sub-Atlantic remains have also a remarkable peculiarity about them which is very instructive in relation to aggregates—they are phosphatized. If phosphatization be connected with the decay of marine organisms it is plain that lying on the sea-bottom must be more favourable to the process than being imbedded even in a porous deposit. No doubt phosphatization can be produced in the heart of a deposit, many autochthonous fossils having phosphatic aureoles—which may have been produced either during the progress of the deposition or subsequently—but, nevertheless, in a large number of cases, when the nature of the deposit, independently of its chemical composition, would lead us to call it an aggregate, we find that it contains phosphatic nodules, and

[1] At the reading of this paper Mr. Lomas instanced also some drifts of dead shells now forming in the Irish Sea, and gave the interesting information that the deposit had been partly phosphatized.

conversely, the great majority of phosphatic deposits are found to be aggregates.

If it be true that an aggregate is formed, as above explained, by means of a strong current sweeping over ground whence it collects the materials in its path, we have to consider what assistance we obtain from it in the matter of chronology. If the fossils are all of one date the deposit is practically of that date also, and we may have a series of aggregates overlying one another, each of a distinct age, in which case their chronology is the same as that of normal deposits. But when aggregates contain fossils of different dates all we can say is, that the deposit is not older than the youngest of its heterochthonous fossils.

When a series of normal tranquil deposits is followed by an aggregate a great change of physical conditions is indicated. The work of rolling along and collecting débris is the result of a disturbance of equilibrium. So soon as this is restored under new conditions the aggregates are left undisturbed, and are followed by a new series of tranquil deposits; or the disturbance may become chronic for a while and produce a series of aggregates. Now geologists indicate these changes of condition by assigning the later deposits to a new series. We may expect, therefore, that aggregates will commonly be basal deposits. As a matter of fact they are more often disputed deposits, but we may safely say that whenever there is a dispute about the lower limit of a series we are almost sure to find that an aggregate is at the bottom of it. The dispute arises from the fact that the deposit contains fossils of older date than its own formation, which, unless its peculiar nature is observed, leads to assigning it either to the age of its older fossils or to drawing a line between two important series in its midst.

It may be well asked—If these aggregates are of so great a significance, have not their peculiarities been noticed long ago? I have no doubt they have been noticed by many field geologists, and certainly it is many years since I first thought about them what is here written; but it is only recently, since ammonites alone have been taken to indicate zones and disputes have arisen, that it has seemed desirable to draw special attention to the nature of these deposits by giving them a name.

I will now point out instances of beds which I take to be aggregates. The first example with which I became acquainted is at Ilminster. In spite of the Geological Survey map, in which Inferior Oolite is marked as lying directly on Lower Lias, the late Mr. Charles Moore had shown that Upper Lias fossils were obtained near that town. When I was specially studying the Lias between 1873 and 1876 I visited the locality, and all I could find was a kind of consolidated gravel in which were imbedded numerous rolled specimens of *Ammonites serpentinus*, *communis*, and *bifrons*, which in Yorkshire occupy distinct horizons, but were here all confusedly mingled together. I came away with the conviction that I had failed to find the true Upper Lias, and that these beds were

disturbed and perhaps redeposited. I now know that, though I certainly failed to find the Fish-bed with its truly autochthonous fossils, it is these very rubble-beds which have been taken to indicate the several ammonite zones. I should now call them an aggregate, and assign the date of its formation to the commencement of the Inferior Oolite period.

Another example is the Gloucestershire Cephalopoda-bed as seen at Frocester Hill. The underlying sands appear to be normal deposits, and they contain Liassic ammonites, but the four feet or more which constitute the capping contain numerous species of ammonites and other fossils all confusedly mixed together, so that no definite subdivision of the bed is possible. The mingling in this bed of Liassic ammonites with others of later date has led to much dispute over its correlation. Its character suggests that it is the commencement of a new series, and the other fossils strongly confirm this view, for many are found in the Inferior Oolite and not in the true Lias, the most noticeable perhaps being *Pholadomya fidicula*. It is not a case of passage beds at all, but of a marked break, with a mere mechanical mingling of fossils of different horizons. If its peculiarity as an aggregate is overlooked, we might unite a part of it with the sands below as forming a single zone—that of *A. striatulus*—as has actually been done, thus comprising within the limits of a zone the junction (according to what appears to me to be the truth) of two formations and certainly of two deposits of an entirely different character, and containing to a large extent a different fauna.

It was a similar phenomenon, observed in Russia last year on the occasion of the visit of the International Geological Congress, that persuaded me of the great importance of observing the character of these aggregates, so as to avoid the confusion that otherwise arises. In the upper part of the "Jurassic" rocks of that country, there occurs a well-marked ammonite whose transverse ribs seem collected into bundles, and hence it is called *Ammonites* (or *Virgatites*) *virgatus*. This species is taken as a zonal ammonite, and all deposits which contain it are grouped together as a single zone by those who are guided by ammonites alone. In the greater number and most accessible of its localities it occurs as a heterochthonous fossil, in spite of which it has been taken to characterize the epoch of the deposit. In one locality, however, it is found in underlying beds as a truly autochthonous fossil. It there occurs in thin bituminous shales, exactly of the character of our own Upper Kimmeridge clay, and is accompanied by the characteristic fossils, *Lingula ovalis* and *Discina latissima*. There can be no doubt, therefore, that its true home is the Upper Kimmeridge. In the same locality it occurs also in the overlying aggregate deposit as heterochthonous fragments, and is accompanied by a different group of other fossils. We have here, then, the following alternative: either a single ammonite may survive the change from a very tranquil deposit, following on a long series of similar deposits to a tumultuous one of an entirely different material, followed by other tumultuous deposits, and containing an

otherwise distinct fauna (in which case an ammonite is no guide to the history of physical and faunal changes); or the upper bed, though containing the same ammonite, is of later date, the deposit being an aggregate and the fossil heterochthonous, and it marks, as Professor Michalski says, the "first accident of the infra-Cretaceous boreal transgression." In any case, the very distinct nature of the two beds containing the same ammonite cannot be rightly neglected, though the only indication of it, in one of the latest descriptions of the zone, is the heterogeneity implied in the words "Marnes, sables ferrugineux et glauconieux, schistes bitumineux, argiles."

Full of these ideas, I had occasion this spring, in connection with the visit of the Geologists' Association to Bridport, to consider the meaning of that curious deposit in the middle of Thorncombe Cliff, called by Mr. S. S. Buckman "the Junction bed," and claimed by him to contain representatives of at least four separate zones. In explaining the proposed excursion to the Association at their previous meeting, I put forward a sketch of what is here written, and ventured on a prophecy about this bed, which I had never seen and whose lithological structure had not to my knowledge been described in detail, that it would prove on examination to have the characters of an aggregate. A glance at the rock sufficed to show that the prophecy was correct, and I had the satisfaction of hearing some members of the Association who reached it first demonstrate these characters on the spot. I think, therefore, that the views I am here expounding may fairly claim to stand the test of prophecy.

About these four cases I feel pretty certain, but there are several others which more or less probably belong to the same category. The Ludlow bone-bed is possibly one, though its elements being small, the tumultuous character is not so obvious. It is, however, phosphatic, and locally marks the commencement of beds in which the fossils of the underlying rocks are absent and organic remains of a different type take their place. The Rhætic bone-bed of Aust Cliff is probably another. It is full of nodules of all sizes, irregularly arranged, it is phosphatic, and it lies at the base of a new series. The phosphate bed at the base of the Lower Greensand at Potton, with its rolled bones of Jurassic reptiles and fishes, is another. The nodular and phosphatic bed called the "coprolite bed" at Speeton, and the "compound nodular bed" above it, occupying about the horizon of the Russian deposit, and, like it, marking, in my opinion, the commencement of a new series, are further examples. The mixed bed at Beer, recorded by Mr. Jukes-Browne as containing the two zonal fossils *Pecten asper* and *Ammonites Mantelli*, may be similarly explained. The "Cambridge Greensand," which has been shown by the same author to contain both autochthonous and heterochthonous fossils, is in like manner the base of an unconformable series. And, finally, the Mammalian bed at the base of the Red Crag, with its huge rolled bones, its crabs from the London Clay, and its nodules with enclosed ammonites, completes the list of the best known of these aggregates in this country; and they are not wanting, as I can testify, on the Continent.

I am not here concerned to prove the correctness of these suggestions in every case. It is quite enough to draw the attention of geologists to the necessity of looking out for and interpreting these aggregates; they will then determine, step by step, which deposits ought rightly to be included in the category.

II.—On the Revision of South Wales and Monmouthshire by the Geological Survey.[1]

By A. Strahan, M.A., F.G.S.

[Communicated by permission of the Director-General.]

THE original geological survey of South Wales was made under the direction of Sir Henry de la Beche. The exact date of its commencement is uncertain, but I am informed by Mr. Aveline that in 1840, when he joined, the staff was engaged in the neighbourhood of Cardiff, and in 1841 Ramsay on his appointment found that the survey had progressed westwards into Pembrokeshire, and was at work at Tenby and St. David's.[2] By the end of 1845 the maps had all been published. A complete list of the names which appear on them consists of H. T. de la Beche, J. Phillips, D. H. Williams, A. C. Ramsay, W. T. Aveline, J. Rees, T. E. James, W. E. Logan, H. W. Bristow, and H. B. Woodward.[3]

Previously, however, to the entry of the Survey into South Wales, a considerable tract had been mapped by Sir W. E. Logan. "Unaided he commenced, in 1831, a geological survey of part of the great South Welsh Coalfield, extending from Crown (Cwm) Avon to Carmarthen Bay, and completed it in seven years, at no small pecuniary sacrifice. Such was the estimate of the accuracy and value of this survey by the late Director of the Geological Survey of Great Britain, Sir Henry de la Beche, that with Sir William's consent it was adopted as part of the national work."[4] At the meeting of the British Association in Liverpool in 1837 Logan exhibited his work, and in 1842 it was referred to by De la Beche as a beautifully executed map.[5] After the lapse of nearly fifty years these maps, admirable though they were considering their date and the circumstances under which they were made, had become obsolete. Not only was the topography scarcely recognizable, but the development of the steam-coal trade had led to the opening out of many of the Monmouthshire and Glamorganshire valleys and the working of what was practically a virgin coalfield. On June 8, 1891, in the House of Commons, Lord Swansea (then Sir Hussey Vivian) asked the Vice-President of the Council whether in

[1] Read before Section C (Geology), British Association, Bristol, September, 1898.

[2] "Memoir of Sir Andrew Crombie Ramsay," by Sir Archibald Geikie, 1895, p. 42; London, 8vo.

[3] Revisions chiefly of the Secondary Rocks in 1864, 1871, and 1872.

[4] An article in *The Times* of July 24, 1862, by Dr. Percy, quoted in "Life of Sir William E. Logan, Kt., LL.D., F.R.S., F.G.S.," by B. J. Harrington, 1883, p. 349; London, 8vo.

[5] Ibid., p. 127.

view of the great importance of the South Wales and Monmouthshire Coalfield, and the fact that the coalfields of Durham, Northumberland, Yorkshire, and Lancashire had been for the most part geologically surveyed on the 6-inch scale, he would give directions that the geological survey of the mineral districts of South Wales and Monmouthshire should be immediately taken in hand and vigorously prosecuted on that scale. Answer was made that it would be arranged with the Director-General that the survey should be commenced as soon as possible, and prosecuted as vigorously as the size of the disposable staff of the surveyors and the exigencies of the other branches of the work would allow. The revision was commenced five weeks later, and its progress up to date forms the subject of the following note.

Until the year 1893 I was engaged alone upon the revision, but in that year I was joined by Mr. W. Gibson, in 1894 by Mr. J. R. Dakyns, and in 1895 by Mr. R. H. Tiddeman. In 1896 Mr. Dakyns retired, and his place was taken by Mr. T. C. Cantrill.

The area over which the revision will extend is embraced in the New Series 1-inch Ordnance Maps, 226–232, 244–249, 261–263, sixteen sheets altogether, and amounts to a little over 2,000 square miles. Of these, three sheets (249, 232, 263) have been published, one (248) is being engraved, while the surveying of two more (231, 262) is nearly complete. The total area surveyed by the end of 1897 amounted to 1,006 square miles, in which 5,011 miles of geological lines had been traced upon the maps.

The work is engraved on the 1-inch New Series Ordnance Maps only, but the lines are all traced in the field on the 6-inch maps. Clean copies of these working maps are deposited in the Office, and can be consulted or copied as soon as the corresponding 1-inch sheet is published. At the same time sheets of vertical sections illustrating the Coal-measures are prepared: two of these, giving series of shaft-sections in Monmouthshire and Eastern Glamorganshire, have been published, and others are in preparation. Explanations to accompany each sheet of the map are also being written: in these the local geology will be briefly explained; but it is proposed to describe the Coalfield as a whole in a separate volume when the revision is complete.

I take this opportunity of acknowledging, on behalf of my colleagues and myself, the invaluable assistance which we have received from the managers, engineers, and surveyors in our work in the Coalfield. Without such aid the mapping would have been impossible, and the unvarying courtesy with which it was rendered has greatly facilitated a task that was far from easy. Of the important information recorded in the "Proceedings" of the South Wales Institute of Engineers, and the Cardiff Natural History Society also, we have freely availed ourselves, acknowledgement of all of which will be made in due course.

In order that the map of the Coalfield should present the structure as conspicuously as possible, it was necessary to subdivide the great mass of Coal-measures which had been represented by

one tint only on the old map. At the eastern end of the field it was apparent that a suitable threefold division of the strata held good, the three divisions not only differing in their mineral contents, but presenting such physical features as lent themselves to the purposes of the geological surveyor. I wish, however, to point out that no correlation is intended with the Upper, Middle, and Lower Coal-measures of other fields. Not only is it extremely improbable that any representatives of the Upper Coal-measures exist, but it is an open question how much of the Middle Coal-measures are present in South Wales. The subdivisions referred to consist of:—

1. An upper series of shales and felspathic sandstones with a few thin seams of coal and ironstone. The sandstones are often indistinguishable from Pennant, but the series is softer on the whole and forms cultivated land of flowing contour. For its base the Mynyddislwyn Vein, a valuable and constant house-coal, served conveniently.

2. The Pennant Series, which in Monmouthshire is made up almost wholly of hard, current-bedded, highly felspathic grit, with a few thin and impersistent coal-seams. This series forms uncultivated moorlands, intersected by deep valleys with rugged sides. At its base occurs the seam variously known as the Red Ash, Tillery, Brithdir, or No. 2 Rhondda.

3. The Lower Coal Series (Steam Coal Series of Glamorganshire), which consists principally of shales and thin beds of quartz-grit. This series contains the thickest seams of coal and the bands or nodules of clay-ironstone which were formerly worked in South Wales. It crops out all along the margin of the Coalfield, but is exposed only in the deepest valleys or along the crests of the anticlines in the more central parts.

Through the eastern end of the field these three subdivisions are readily distinguished, but they expand rapidly westwards, and at the same time sandstones not to be distinguished from Pennant appear in the upper part of the lower series, while measures of the supra-Pennant type replace the upper grits of the Pennant group. They continue, however, to form the most suitable broad divisions that could have been selected, though a further subdivision may become necessary in view of their increasing thickness.

The other rock-groups have been treated on similar principles. The Old Red Sandstone of Monmouthshire at once lends itself to division into an upper series of grits and quartz-conglomerates, a thick mass of red sandstones, and a great underlying deposit of red marls with thin limestones. Special attention has been paid to the relations of these subdivisions to one another in view of the possibility of an unconformity having remained undetected in the middle of the red strata; but though the grits and quartz-conglomerates disappear in Brecknock, no break of any significance in the sequence has yet been discovered. The conformity of the Old Red Sandstone to the Upper Silurian rocks of Usk, however, may prove to be more apparent than real, and must remain an open question for the present.

The Carboniferous Limestone also expands westwards and southwards, for, while only 100 feet thick at Abergavenny, it is 500 to 700 feet in northern Glamorganshire, and attains still greater dimensions in the southern part of that county. The lower portion consists of shales with a more or less persistent limestone below, which constitute the Lower Limestone Shales. In the main mass no subdivision has been made, except that certain light-coloured oolitic bands have been picked out.

The mapping of the Millstone Grit is founded on purely lithological distinctions. Over a large part of the north-eastern crop it consists of a grit (the Farewell Rock of old miners) in the upper part; shales, and sandstones, occasionally with some coal and ironstone, in the middle; and a massive grit, usually crammed with quartz-pebbles, in the lower part. This order, however, does not hold good everywhere, and shales and sandstones are traced as far as practicable, and merely coloured on the map as such. Though perfectly conformable to the limestone, the oncoming of the quartz-conglomerates seems to have been accompanied by some erosion, for they fill small hollows in the topmost limestone, and are even suspected of cutting across some of the beds, so as to simulate an unconformity. Matters are further complicated by the fact that the upper surface of the limestone has undergone extensive dissolution during later ages.

Some fossils which occur in calcareous shales and thin impure limestones in the lower and middle parts of the Millstone Grit are all marine, but in the upper part *Anthracomya* becomes the abundant shell, and indicates an approach to Coal-measure conditions. Marine forms, however, recur at intervals high up in the Lower Coal Series. It will be noticed that there is nothing corresponding to the 'Yoredale Rocks,' or upper part of the Carboniferous Limestone Series of the North of England, nor to the alternating series of sandstones and limestones which border the Flint and Denbigh Coalfields.

The Secondary Rocks which fall within the revised area include Trias (Keuper or New Red Marl), Rhætic, and Lower Lias. These strata were deposited along a land which was undergoing gradual submergence after prolonged exposure to subaerial denudation. The New Red Marl, consequently, was irregularly distributed in what must have been bays diversified by numberless islands, and the old shore-lines, though subsequently buried, have been revealed by denudation, so that it is often possible to examine the cliffs against which the Triassic waves beat and the talus, more or less water-worn, which fell from them. The continued sinking of the land led not only to the Rhætic overspreading the Trias, and extending beyond it, but to the Lias eventually overlapping all earlier deposits. Each formation, as it overlaps its predecessor and comes into contact with the Palæozoic rocks, becomes conglomeratic, and it thus happens that a conglomeratic subdivision though actually continuous is of Triassic, Rhætic, and Liassic age in different parts of its outcrop; a state of affairs which is not easily represented by the usual methods of colouring a geological map.

The boundary between the New Red Marl and the Rhætic has hitherto been taken at the base of some green marls which graduate downwards into the Red Marls, but during the revision it became evident that the only satisfactory base to the Rhætic occurred above the Green Marls and at the base of the black shales of the *Avicula contorta* zone. At this horizon there is generally a grit or small quartz-conglomerate which taken with the incoming of the Rhætic fauna indicates a somewhat sudden change of physical conditions. It marks, in fact, the first complete invasion of this area by the sea.

One of the most important parts of the revision has consisted in the tracing of the various folds and faults through the Coalfield. The main anticlinal and synclinal axes are of course brought into prominence on the map by the subdivision of the measures before referred to. Thus the difference of tint shows the positions of the two deep synclines which introduce the Upper Coal Series at Caerphilly and Llantwit on the south side, and at Blackwood and Gelligaer on the north side of the main anticline; while the anticlinal axis is itself brought into prominence by the fact that it brings the Lower Coal Series up to the surface at intervals along its course. Especially, also, attention may be directed to the contrast presented by the long dip-slopes of the north crop of the Coalfield to the straight and narrow strips along the highly inclined south crop. Of the numerous flexures which have been traced in the Palæozoic rocks outside the Coalfield it is sufficient to state that they run in about the same direction as those mentioned above, and that they do not affect the Secondary Rocks, which in fact pass horizontally across them. These east and west flexures are consequently assumed to be pre-Triassic.

To this series also we believe the great Vale of Neath disturbance and some other kindred folds to belong. This great faulted fold seems to have attracted but little notice hitherto, though it displays many remarkable features, among others a thrust by which Carboniferous Limestone has been pushed over a large thickness of Millstone Grit. It will be remembered that the Carboniferous Rocks of Somerset were still more intensely plicated and overthrust in pre-Triassic times, and that there also the disturbances run in a general east-and-west direction.

The set of faults which run about north-north-west with such remarkable persistency is a well-known feature of the Coalfield. Some of them can be traced out into the Secondary area, and are there found to dislocate the Secondary Rocks equally with the Carboniferous. While, therefore, they are obviously post-Liassic, they may be of very much later date.

The exact representation of the faults, of whatever age, upon the map is of the greatest importance in the Coalfield, and is managed as follows:—The surface-position of the fault is indicated by a white line, or by a broken white line where the exact position is uncertain. If the fault has been proved in the workings of the Mynyddislwyn Vein, its underground position in that vein is shown by a red line, if in the Tillery Vein by a yellow line, and if in the Lower Coals

by a blue line. Thus a normal fault completely proved would be represented by four lines, the order in which the lines occur indicating the direction, and their distance apart the angle of the hade. A further difficulty remains, however; for the plan-position of a fault encountered in any vein in working up to it from the east would not be the same as the plan-position of the same fault in the same vein if worked up to from the west, owing to the hade. In a fault of 100 yards the discrepancy would amount to 35 or 40 yards, and it becomes necessary to record also from which side the fault was proved, which is not always easily ascertained in old workings. The coloured lines referred to are used on the 6-inch maps only: on the 1-inch maps the underground faults are all shown by yellow lines to avoid undue complication.

The glacial deposits are mapped simultaneously with the solid geology, and are shown on the edition of the map for superficial geology. With the exception of the admirable work of Professor Edgeworth David, and observations by the late Rev. W. S. Symonds, they have not attracted so much attention as they deserve, for South Wales formed a small independent centre of glaciation and exhibits phenomena of great interest. The greater water-partings of the present day formed the ice-partings of the Glacial Period, and the principal valleys gave the route to the ice-flow. Thus a great mass of drift was transported from Brecknock round the north-east corner of the Coalfield down the Usk Valley as far as the depression occupied by the Usk Branch Railway. Another part was pushed over a minor water-parting into the Rhymney Valley, but principally escaped along the Taff Valley, traversing the entire Coalfield and emerging by the ravine at Walnut Tree; while a third portion flowed south-westwards along the Neath and other valleys towards Swansea Bay. The drift consists in part of coarse gravels or fine gravel and sand, and forms characteristic mounds or ridges between which are inclosed innumerable water-logged hollows, or meres. Nearer to its source, however, it becomes an extremely tough boulder-clay packed with glaciated boulders. The composition of the deposit, the direction of the longer axes of the mounds, and, lastly, a large number of striations on rock-in-place combine in determining the directions assigned to the ice-flow. The southern limit to which the ice reached is no less clearly marked than its birthplace, for the gravels get finer and thinner, and eventually die away, sometimes before reaching the shores of the Bristol Channel.

III.—Blind Trilobites.

By F. R. Cowper Reed, M.A., F.G.S.

(*Continued from the October Number*, p. 447.)

(2) Order Opisthoparia.

We now come to the second order of the Trilobita, which Beecher (loc. cit.) calls the Opisthoparia. In common with the third order, the Proparia, compound paired eyes are usually present, and these are invariably situated on the free cheeks, which form part of the dorsal surface of the head-shield.

The development of several genera of the order Opisthoparia has been traced in detail, and in the family Conocoryphidæ, which is placed by Beecher lowest in the order, we find the characters of a pre-adult stage of certain Olenidæ preserved till maturity. In fact, the adult *Conocoryphe* is in the nepionic stage of such genera as *Ptychoparia* and *Sao*, and this fact shows that it belongs to a lower phylogenetic rank. The free cheeks are very narrow and marginal, and the eyes are absent or very rudimentary. Owing, unfortunately, to the loose manner in which the name *Conocoryphe* has been applied, and the confusion arising from its different usage by palæontologists, it has frequently been stated that the genus includes a majority of species possessing compound eyes and a few which are blind; and, consequently, it has been quoted as analogous to those genera of which the species living in twilight or darkness have almost or completely lost their eyes. Conclusions based on this mistaken analogy are naturally erroneous and misleading. A structural feature which is really of high phylogenetic significance has been misinterpreted as an adaptive modification induced by certain conditions of existence.

The name *Conocoryphe* should be applied in the manner in which its author, Corda,[1] first used it, when he took as its type the well-known blind form *Conocoryphe Sulzeri*. Matthew has insisted on this point, and when the genus is thus restricted so as only to include forms agreeing with this type in important structural characters, a large number of species which are commonly ascribed to this genus have to be excluded. Thus, of the numerous British species which have been described as belonging to the genus *Conocoryphe*, only *C. bufo* (Hicks) and perhaps *C. humerosa* (Salter) can be admitted.[2] Barrande[3] included in his genus *Conocephalites* a large number of species possessing eyes, as well as *C. Sulzeri* and others devoid of eyes, so that *Conocephalites* practically covered Corda's genera *Ptychoparia*, *Ctenocephalus*, and *Conocoryphe*.

Walcott[4] says that the genus *Conocoryphe*, in its restricted sense, is identical with Emmons' genus *Atops*, and Vogdes[5] takes Corda's *Conocoryphe Sulzeri* (Schlotheim[6]) as the type of the genus *Atops*. Beecher,[7] however, takes this species as the type of the genus

[1] Hawle and Corda, Prodr. Mon. Boh. Trilob., 1847, p. 24, t. ii, f. 10.

[2] *C. Homfrayi* (Salter) is stated to possess eyes, but from a careful examination of the type-specimen, which is much compressed and distorted, I have much doubt if they truly exist. In *C. Lyelli* (Hicks) the free cheeks are marginal, and the eyes which have been described appear to me to be merely the swollen ends of the ocular ridges on the fixed cheeks, and their visual function is doubtful. In cephalic structure this species agrees so closely with the *Conocoryphe*, s.str., of Corda, that after carefully examining the type-specimen, I am inclined to consider it a true member of the genus *Conocoryphe* and to be devoid of compound eyes.

[3] Barrande, Syst. Sil. Boh., vol. i, p. 415.

[4] Bull. 30 U.S. Geol. Surv., 1886, p. 203; Amer. Journ. Sci., ser. III, vol. xxxiv (1887), p. 197; Fauna of the Olenellus Zone, 1890, p. 647; S. W. Ford, Amer. Journ. Sci., ser. III, vol. xix, p. 152.

[5] Bibliogr. Pal. Crust. (California, 1893), p. 255.

[6] Schlotheim, Nachträge z. Petrefakt., ii (Gotha, 1823), pl. xx, fig. 1.

[7] Amer. Journ. Sci., vol. iii (1897), p. 188.

Conocoryphe, and he considers *Atops* to be distinct and its type to be *A. trilineatus* (Emmons). Linnarsson[1] uses the name *Conocoryphe* in the same restricted sense as Walcott. Zittel[2] employs the name *Conocephalites* in the broad manner of Barrande, including the genera *Solenopleura*, *Ptychoparia*, *Conocoryphe*, s.str., etc.

Matthew,[3] perceiving the heterogeneous composition of Barrande's *Conocephalites*, splits it up into two divisions, one possessing eyes and the other possessing no eyes. The blind division constitutes, according to him, the subfamily Conocoryphinæ, which consists of two genera—(1) *Ctenocephalus*, type *Ctenocephalus Barrandei* (Corda) =*Conocephalites coronatus* (Barr.), with subgenus *Hartella*, probably including *Conocoryphe solvensis* (Hicks); (2) *Conocoryphe*, type *Conocoryphe Sulzeri* (Schloth.), with a subgenus *Bailiella*, to which perhaps *Conocoryphe bufo* (Hicks) belongs. This subgenus *Bailiella* is not synonymous with Salter's *Erinnys* (type *E. venulosa*, Salter) as Beecher suggests.[4] In *Bailiella*, as defined by Matthew (type *B. Baileyi*, Hartt), there is a facial suture which cuts off the lateral third of the marginal fold. Matthew's[5] other division of Barrande's genus *Conocephalites* consists of those possessing eyes and includes the Ellipsocephalidæ and Ptychoparinæ (*Ptychoparia*, *Liostracus*, *Solenopleura*). Hoernes,[6] though remarking on the fact that the facial suture in *C. Sulzeri* and *C. coronatus* is almost marginal, separating only a narrow band-like free cheek, and in this respect differing from that of the other species, yet uses the name *Conocoryphe* in the broad sense so as to include a multitude of very different forms. Koken[7] puts Corda's *Ctenocephalus* and *Conocoryphe* into one genus, which he calls *Conocoryphe*.

The generic name *Conocoryphe* is here employed in the manner which Matthew (loc. cit.) has defined. To the genus *Ctenocephalus*, as also defined by him, belong the British species *Ct. coronatus* (Barr.) and *Ct. solvensis* (Hicks). In both Europe and America these two genera are restricted to the Cambrian, and are especially characteristic of the lower part, which is just as we should expect from their morphology and phylogeny.

Of the other genera belonging to this family we have in Europe *Erinnys* (Salter), *Caransia* (Hicks), *Dictyocephalites* (Bergeron),[8] and the imperfectly described forms[9] *Aneucanthus* (Angelin) and *Eryx* (Angelin).

Erinnys,[10] of which only one species, *E. venulosa* (Salter), is known,

[1] "Om Fauna i Kalken med Conocoryphe exsulans": Sver. Geol. Undersokn., ser. C, No. 35 (1879).
[2] Handb. v. Palæont., vol. ii, p. 600.
[3] Trans. Roy. Soc. Canada, vol. ii (1884), sect. iv, p. 102.
[4] Amer. Journ. Sci., vol. iii (1897), p. 188.
[5] Trans. Roy. Soc. Canada, vol. v (1887), p. 123.
[6] Manuel de Paléont. (traduit), 1886, p. 462.
[7] Die Leitfossilien, 1896, pp. 21 and 360.
[8] Bull. Soc. Géol. France, ser. III, vol. xxiii (1895), p 469, pl. iv, figs. 4, 5.
[9] Pal. Scand., pp. 4, 5, pl. v.
[10] Brit. Assoc. Report, 1865, p. 285; Quart. Journ. Geol. Soc., vol. xxviii (1872), p. 177.

is considered by some palæontologists to be identical with *Harpides* (Beyrich); but *Harpides* is described and figured as possessing eye-spots, whereas *Erinnys* has merely the branching nervures on the cheek, and there are other important differences in its structure which appear amply sufficient to separate it generically.

Carausia (Hicks)[1] is in every respect closely allied to *Erinnys*, and neither genus shows any free cheeks or dorsal facial sutures. Both genera are found in the Menevian beds.

Dictyocephalites (Bergeron) may eventually prove not to be a blind form. It occurs in the Ordovician of Saint-Chinian, but only two imperfectly preserved specimens of it are known. Bergeron considers that it shows resemblances to *Eurycare* (Angelin), but the structure of the head is more suggestive of *Harpides*, and the tubercles on the cheeks resemble eye-spots.

In America there are the genera *Avalonia* (Walcott) and *Bathynotus* (Hall), which, however, may possibly not be blind. *Harttia* (Walcott) is probably only of subgeneric rank.

Beecher (loc. cit.) says in his concluding remarks on this family that "the general average of the characters in the Conocoryphidæ represents the main larval features throughout the other families" of the order Opisthoparia to which it belongs.

The genus *Carmon* (Barrande)[2] is placed by Beecher in this family, but Zittel[3] puts it with the Proetidæ. Only two species of this genus have been described. Of these the first, *C. mutilus* (Barr.), occurs in Étage D*d* 5, and the second, *C. primus*, in D*d* 1. The important point for us to notice is that *C. mutilus* has no eyes or facial suture, whereas *C. primus* possesses both. Barrande (loc. cit.) says these differences are only of specific importance, and he instances *Illænus*, with its blind and eye-bearing species, as an analogous example. Such may be the true explanation, and it is especially probable to be so if the true affinities of *Carmon* are with the Proetidæ. But *C. primus* is only known to us by a head-shield, and though according to Barrande the hypostome of *C. mutilus* resembles that of *Proetus*, yet the thoracic segments and pygidium are more suggestive of the Conocoryphidæ. If its real relations are with the latter family we must regard *C. mutilus* as a solitary survival of a primitive type, and *C. primus* then probably belongs to a different and higher genus. If, on the other hand, we consider that its general characters indicate affinities with higher and eyed forms, such as *Proetus*, we must either regard the absence of eyes and the primitive characters of the head-shield as a sign of reversion or degeneration, probably conditioned by a certain environment, or as an analogous case to *Areia*, which I have described[4] as a primitive form belonging to the Cheiruridæ, in which the normal ontogenetic development has been arrested irregularly

[1] Quart. Journ. Geol. Soc., vol. xxviii (1872), p. 178, pl. vi.

[2] Barrande, Syst. Sil. Boh., vol. i, p. 915, pl. xxxiv, fig. 43. Ibid., Suppl., vol. i, p. 19, pl. ii, figs. 4–6; pl. xiv, fig. 45.

[3] Handb. Palæont., vol. ii, p. 625.

[4] Geol. Mag., Dec. IV, Vol. V (1898), p. 206.

so that the head-shield has retained its early larval features. I do not, however, see that the evidence in favour of putting *C. mutilus* with the Proetidæ, or any other such high group, is stronger than that of putting it in the Conocoryphidæ. It is to be noticed, moreover, that the genus *Proetus* has not been recorded from Étage D, except the doubtful species *Pr.*? *primulus* (Barr.) from D*d* 1 and *Pr.*? *perditus* (Barr.) from D*d* 5.

There is considerable uncertainty about the true position of the genus *Holocephalina* (Salter).[1] It is placed by Zittel in his somewhat heterogeneous family Conocephalidæ, together with *Arionellus*, to which, as Salter remarks (loc. cit.), it shows some points of resemblance. There seems to me little reason for associating it with the Asaphidæ, as Beecher does in his scheme of classification. It is very doubtful if eyes are present in either of the two known species, though Salter records them on the minute free cheeks of *H. primordialis*, at the base of the genal spines. The free cheeks in this species consist almost entirely of the genal spines and do not extend along the cephalic margin, and in this way remind us of those forms (e.g. *Trinucleus*) in which the eyes are absent.[2] In *H. inflata* no genal spines or free cheeks are known, and it appears to me that this genus is in reality a Conocoryphid with incipient free cheeks, as in the metaprotaspis stage of *Ptychoparia Kingi*,[3] and that the loss of segmentation in the glabella and other signs of specialization are secondary features, as in *Agnostus*. The fact that *Holocephalina* is confined to such an early stratigraphical horizon as the Menevian is also against regarding it as a degraded or degenerate higher form. *Arionellus* is an allied genus, but it has well developed, though narrow, free cheeks, bearing distinct eyes, which are a mark of a higher stage in the evolution of the cephalon.

Passing now to the family Olenidæ, which is for the sake of convenience split up by Beecher into four subfamilies, we meet first with a group of genera which are generally considered to possess eyes on the free cheeks, though varying much in size and degree of development. But with regard to the genus *Paradoxides* in the subfamily Paradoxinæ, there has long been much dispute as to whether it was possessed of the power of vision or not. By some palæontologists the eye-socket is held to have been occupied by no functional visual organ, but generally this genus is described as furnished with long narrow eyes. Beecher (loc. cit.) does not make any mention of its supposed blindness, nor does Zittel. Salter, Hicks, and other British writers who have described its species always speak of the presence of eyes without suggesting their non-functional nature; but the visual surface and lenses have never been described, and the surface of

[1] Q.J.G.S., vol. xx (1864), p. 337, pl. xiii, fig. 9; vol. xxviii (1872), p. 178, pl. vi, figs. 8–10.

[2] Barrande (Syst. Sil. Boh., Suppl., vol. i, p. 156) remarks that, judging from the figures, this species seems to be devoid of eyes.

[3] Amer. Geol., vol. xvi (1895), pl. viii, fig. 6.

the eyes is always spoken of as non-reticulate. Rafinesque[1] puts *Paradoxides* in the group Anopsites, the members of which possess no eyes. Green,[2] in describing *Paradoxides Harlani*, says that "the organs of vision appear entirely wanting." Milne Edwards[3] states that there are no reticulate eyes visible in this genus but that sometimes there exists in their place a fairly distinct scutiform elevation. Goldfuss,[4] however, includes *Paradoxides* amongst those trilobites possessing smooth or finely reticulate eyes, which, he says, are only indicated as cracks in the casts.

After enumerating the genera in which the visual surface is unknown, Barrande[5] says that it is due to the imperfect state of preservation in which the Bohemian trilobites of this group occur, but that this fact does not hinder one from recognizing in the general form of the eyes that they have the closest analogy with the reticulate eyes of other genera in which the visual surface has been observed. He further remarks that *Paradoxides*, *Olenus*, etc., were considered blind by the older palæontologists, doubtless because the eyes of these genera have usually less prominence, which is owing perhaps to their natural conformation or the effects of compression. The eyes of *Paradoxides* are described by Barrande as belonging to the annuloid type. Subsequently he speaks[6] of the genus as provided with large eyes in contradistinction to its blind contemporaries.

Emmrich[7] had previously argued for the existence of eyes in *Paradoxides*, and thought the reticulation of the surface might be microscopic.

Steinmann and Doderlein[8] apparently accept the view that the eyes were functionless.

Matthew,[9] however, in his long description of various species of *Paradoxides* from the St. John group, makes no remarks which would lead one to imagine that the eyes were absent or functionless. Nicholson, in his "Manual of Palæontology" (p. 519), describes the eyes as long, reniform, and smooth, and does not hint at the genus being blind. Suess[10] and Neumayr[11] argue in favour of *Paradoxides* being blind because of its association with blind forms.

It should be remembered that some genera (*Arionellus*, *Sao*, *Ellipsocephalus*) have the visual surface of their eyes so rarely or so badly preserved, that for a long time they were held to be blind.[12] If the eye of *Paradoxides* be holochroal and the cornea smooth, thick, and continuous, so as to be practically indistinguishable from the

[1] Atlantic Journ. and Friend of Knowledge, vol. i (1832), p. 71.
[2] Amer. Journ. Sci., ser. 1, vol. xxxv (1834), p. 336.
[3] Hist. Nat. Crust., vol. iii (1840), p. 339.
[4] Leonh. and Bronn, Jahrb. f. Min., 1843, p. 546.
[5] Syst. Sil. Boh., vol. i, pp. 131, 145.
[6] Ibid., Suppl., vol. i, p. 161.
[7] Jahrb. f. Min., 1845, p. 18.
[8] Elemente d. Palæont., 1890, p. 490.
[9] Trans. Roy. Soc. Canada, vol. ii (1884), sect. iv.
[10] Das Antlitz der Erde, vol. ii, p. 274.
[11] Erdgeschichte, vol. ii, p. 52.
[12] Zittel, Handb. Palæont., vol. ii, p. 572.

general cephalic integument, the visual surface may very easily escape detection. It is not, however, possible with our present knowledge to determine positively whether the eyes were functional or not. But from the analogy of other forms which were long thought to be blind, and in the absence of indisputable evidence that *Paradoxides* was devoid of the power of vision, we seem to be on the safer side in holding that the long slit-like eyes were of use to the animal. Moreover, it has never been satisfactorily demonstrated that eyes of this type are indicative of degeneration; and if the form called *Hydrocephalus* by Barrande be indeed the young of *Paradoxides*, as supposed by Beecher,[1] the long eye-lobes are a larval feature in the genus. The undoubted young of *Olenellus*, which belongs to the same subfamily, show also the same feature. The remarks which have been made about the eyes of *Paradoxides* would apply also to a large extent to the genera *Olenellus* (with its subgenera *Holmia*, *Mesonacis*, *Olenelloides*), *Plutonides*, and *Zacanthoides*.

The genus *Anopocare* of Angelin,[2] which is described by him as devoid of eyes, may be an immature Olenid, but I have not examined the type.

With respect to the genus *Telephus* (Barrande),[3] there is some uncertainty whether all the species are without eyes or whether some are blind and some are not. What is taken as possibly representing the palpebral lobe in some is described as the cephalic border in others, and we are not in a position to determine which is the correct view. Judging from the figures and descriptions published, I am inclined to think that it possessed an elongated eye-lobe as in *Olenellus*, *Anopolenus*, etc., and therefore that we must exclude it from the list of blind forms.

We turn now to the family Illænidæ, in which it is most interesting to find that the genus *Illænus* contains undoubtedly a few blind species. The whole head-shield of these blind forms is modified in a reversionary manner, so as to exhibit characters which we have seen mark a definite stage in the phylogeny of the trilobites, or a particular larval stage in those forms which have a complete, non-condensed, and non-accelerated development.

In all the families above the Conocoryphidæ, free cheeks bearing compound eyes are the characteristic feature in the adult, and in the higher and later genera the free cheeks normally exceed in size the fixed cheeks and are of a triangular shape. It is only in the lower forms and pre-adult stages of the higher ones that the free cheeks are narrow, marginal, and band-like. But this latter primitive condition of the free cheeks is found in the blind *Illæni*, in which the facial suture pursues a simple course subparallel to the margin of the cephalon, and the fixed cheek shows no trace of a palpebral lobe nor the free cheek of a compound eye. As these blind species

[1] Amer. Journ. Sci., ser. III, vol. xlvi (1893), p. 142.

[2] Pal. Scand., p. 50, pl. xxvii, figs. 1 and 2.

[3] Barrande, Syst. Sil. Boh., vol. i, p. 890, pl. xviii; ibid., Suppl., vol. i, p. 155. Angelin, Pal. Scand., p. 91, pl. xli, figs. 21–3. Törnquist, Undersokn. Siljansom. Trilobitf.: Sver. Geol. Undersokn., ser. C, No. 66 (1884), p. 89.

agree in all other respects with those *Illæni* possessing eyes and the normal Illænid structure of the head, we must conclude that they have suffered degeneration of their visual organs, and that it has been accompanied by a reassumption of those primitive features in the free cheeks and facial sutures which are met with in the blind Conocoryphidæ. What has led to the loss of eyesight we will consider later, but we see that we must at any rate regard their condition as a modification of the normal organization of the genus, and not as phylogenetically significant. In other words, we have here to deal with a special adaptive character in contradistinction to one marking a stage in the regular evolution of the group. Similar reversionary or degenerate types in a highly specialized genus or in a family of high morphological rank are occasionally found amongst modern crustacea when surrounded by abnormal conditions in which these organs of special sense are not required.

The blind species of *Illænus* are the following :—

I. leptopleura (Linnarsson),[1] from the *Trinucleus* beds of Sweden.
I. Angelini (Holm),[2] from the same beds and locality.
I. cæcus (Holm),[3] from the Lyckholm Beds (Stage F 1) of Russia, the Keisley Limestone of England[4] and the Kildare Limestone of the Chair of Kildare.[5]
I. galeatus (Reed),[6] from the Keisley Limestone.
I. aratus (Barrande),[7] from Étage D*d* 1, Bohemia.
I. Katzeri (Barrande),[8] from Étage D*d* 1, Bohemia.
I. Zeidleri (Barrande),[9] from Étage D*d* 5, Bohemia.

It is noticeable that the blind forms in Sweden and Bohemia occur in fine argillaceous beds, while in Russia and the British Isles they are found in limestone. This is a significant fact, as it indicates that they lived under entirely different physical conditions in the several areas, and that there is a possibility that different causes have led to the same modification.

In the family Proetidæ no blind genus is known, but in two species of *Proetus*—*P. dormitans* (Richter) and *P. expansus* (Richter)[10]—no eyes have been found. None of the Bronteidæ or Lichadidæ are known to be blind, but amongst the Acidaspidæ there is one blind species of *Acidaspis*, *A. myops* (Richter),[11] which occurs in the

[1] Holm, "De Svensk. Art. Trilobitslag. Illænus" : Bih. t. k. Vet. Akad. Handl., Bd. vii (1882), No. 3, p. 118, t. iv, f. 28 ; t. vi, f. 11.
[2] Holm, ibid., p. 120, t. iv, f. 29.
[3] Holm, "Rev. d. ostbalt. Silur. Trilob.," Abth. iii, Illæniden : Mem. Acad. Imp. Sci. St. Petersb., ser. VII, t. xxxiii (1886), No. 8, p. 162, t. xi, f. 11*a–d*.
[4] Quart. Journ. Geol. Soc., vol. liii (1896), p. 413.
[5] Ibid., p. 593.
[6] Ibid., p. 414.
[7] Syst. Sil. Boh., Suppl., vol. i, p. 68, pl. xiv, figs. 43, 44.
[8] Bull. Soc. Géol. France, vol. xiii (1856), p. 532. Syst. Sil. Boh., Suppl., vol. i, p. 72, pl. v, figs. 28–37 ; pl. vi, figs. 1–4 ; pl. xiv, fig. 36.
[9] Syst. Sil. Boh., Suppl., vol. i, p. 74, pl. iii, figs. 20–29.
[10] Richter, Zeitsch. f. Deutsch. Geol. Gesell., vol. xv (1863), p. 659 ; ibid., vol. xvii (1865), p. 361.
[11] Richter, op. cit., vol. xv (1863), p. 670.

Tentaculites beds of the Continent. In this case, as with the blind *Illæni*, we must regard the loss of eyes as a secondary acquired feature and an adaptation to certain conditions of life.

(3) Order Proparia.

We come now to the highest order of the trilobites, which Beecher has termed the Proparia. It comprises the families Encrinuridæ, Calymenidæ, Cheiruridæ, and Phacopidæ, and we find amongst them the blind genera *Dindymene*, *Prosopiscus*, *Areia*, and *Placoparia*.

The genus *Dindymene* (Corda)[1] belongs to the Encrinuridæ, which is morphologically the lowest family in the order. In this genus free cheeks and compound eyes are wanting, and the facial suture is presumably marginal. The head, therefore, in spite of the secondary specialization of the glabella as shown by its loss of segmentation, exhibits the primitive characteristics of the Hypoparia. Probably this genus is phylogenetically as well as morphologically at the base of the family, as is the case with *Areia* in the Cheiruridæ. It is possible that the tubercle on each fixed cheek in some species (e.g. *D. Hughesiæ*, Roberts) may be a visual organ similar to the eye-spot in the young *Trinucleus*, but of this we have no proof. Only two British species are known, i.e. *D. Hughesiæ* (Roberts),[2] from the Bala beds of Norber Brow, and *D. Cordai* (Etheridge and Nicholson)[3] from the Drummuck beds of the Girvan district.

The genus *Prosopiscus* (Salter),[4] of which little is known, was described as possessing no eyes, and is placed by Beecher amongst the Encrinuridæ.

The genera *Areia* (Barrande) and *Placoparia* (Corda)[5] should probably be included amongst the Cheiruridæ; and from a number of structural features exhibited by these two forms we are led[6] to regard them as early and primitive types of the family in which the ordinary ontogenetic development has been partly arrested, resulting in the retention of some larval characters in combination with secondary modifications. When the loss of visual organs is the result of degeneration or special adaptation, only the head-shield is affected, as is shown by the blind *Illæni*; the process of degeneration does not affect, as a rule, other parts of the body unless their functions are correlated with the sense of sight. The condition of blind cave-animals, with closely allied species provided with eyes outside the cave, teaches us this fact also. So that we are debarred from considering the larval characters in the general body-structure of *Areia* and *Placoparia* as concomitant with or resultant from the absence of eyes. These larval features are not signs of degeneration or adaptation, but are typical of a certain early stage in the evolution of the Cheiruridæ. The early stratigraphical horizon

[1] Hawle and Corda, Prodr. Mon. Boh. Trilob., 1847, p. 119.
[2] S. H. Reynolds, Geol. Mag., Dec. IV, Vol. I (1894), p. 108, Pl. IV, Figs. 1, 5.
[3] Monogr. Sil. Foss. Girvan, fasc. i (1878), p. 115, pl. viii, fig. 8.
[4] Salter and Blanford, "Palæont. of Niti," 1865.
[5] Hawle and Corda, Prodr. Mon. Boh. Trilob., 1847, p. 128.
[6] Geol. Mag., Dec. IV, Vol. V (1898), p. 206.

on which these two genera occur (i.e. *Areia* on Dd 1 and Dd 5 in Bohemia; *Placoparia* in Dd 1 and Dd 2 in Bohemia, and in the Llanvirn of Wales, etc.), and their disappearance before the family reached its maximum of differentiation, point to the same conclusion.

None of the Calymenidæ are analogous to these primitive Cheiruridæ, and none are without eyes.

Amongst the Phacopidæ, one species of the type genus, *Phacops*, is supposed to be without eyes, though possessing the features of one of the most differentiated and latest groups of the genus. This species is *Ph.* (*Trimerocephalus*) *lævis* (Münster), and it occurs in the Upper Devonian of England. Salter,[1] while describing the species as devoid of eyes, says that very probably their apparent absence is only due to the imperfect preservation of the specimens. McCoy,[2] however, takes the absence of eyes as one of the characteristics of the subgenus. Barrande[3] reviews the history of this form in some detail, and accepts the view that it is blind. If this be indeed the case, it must be analogous to the blind species of *Illænus*, and of no phylogenetic or ontogenetic significance. For the degeneration of the visual organs we must again seek some pathological or external cause.

Doubtful Genera.

We have now been through all the families of the Trilobita, and discussed their blind forms, but there still remain a few blind genera the position of which is doubtful. We may first mention the blind genus *Typhloniscus* (Salter),[4] from the Lower Devonian of South Africa, which was assigned by Salter to the Cheiruridæ. Another genus whose affinities are uncertain is *Cyphoniscus* (Salter).[5] Only one species (*C. socialis*, Salter) is known, and it occurs in the Upper Bala Limestone of the Chair of Kildare and in the Keisley Limestone. It possesses a facial suture, but no eyes have been observed, and the free cheeks themselves have not so far been discovered. Salter[6] was of the opinion that eyes were present because there were probably separable free cheeks, but as it is now definitely ascertained that there are many blind species which have marginal free cheeks of a narrow band-like form cut off by a simple facial suture, as in this species, it appears probable that *Cyphoniscus* was also blind.

Tiresias (McCoy),[7] first described from the Chair of Kildare Bala Limestone, but recently also from the Keisley Limestone,[8] is destitute of eyes and appears to be allied to *Ampyx*, but only the head-shield is known. *Isocolus* (Angelin),[9] of which the type is *I. Sjogreni*

[1] Mon. Brit. Trilob., 1864, p. 16.
[2] McCoy. Syn. Brit. Pal. Foss., 1851.
[3] Barrande, Syst. Sil. Boh., Suppl., vol. i, p. 158.
[4] Geol. Trans., 2nd ser., vol. vii (1846), p. 221, pl. xxv, fig. 14. Mon. Brit. Trilob., note on p. 60.
[5] Proc. Brit. Assoc., 1852, p. 60.
[6] Mem. Geol. Surv. Org. Rem., dec. vii, pl. ix.
[7] Syn. Sil. Foss. Ireland, 1846, p. 43, pl. iv, fig. 1.
[8] Reed, Quart. Journ. Geol. Soc., vol. lii (1896), p. 410.
[9] Pal. Scand., p. 58, pl. xxxiii, fig. 8.

(Ang.) from Dalecarlia, is a blind genus, but incompletely known. Törnquist[1] describes it from the *Leptæna* Limestone.

The two genera, *Conophrys* (Callaway)[2] and *Shumardia* (Billings),[3] may be larval forms. Both are blind. Brögger[4] has suggested that the species *Conophrys pusilla* (Sars), from the *Ceratopyge* beds of Sweden, may be the young of *Ceratopyge forficula*. The only known British species is *Conophrys salopiensis* (Callaway) from the Shineton Shales.

The type species of *Shumardia* is *Sh. granulata* (Billings) from Point Levis, Quebec. *Sh. glacialis* (Billings) seems generically distinct.

Origin of Blind Forms.

We have now passed briefly in review all the known blind forms of trilobites, and we see that they fall into two natural divisions, of which the first group comprises those in which eyes are not present because of the low phylogenetic and morphological rank of the genera in question, as their general structure and stratigraphical appearance indicate ; and the second group includes those which are generically identical or closely allied to forms possessing eyes, are of high phylogenetic rank, and have lost their visual organs by a secondary modification, presumably as a result of adaptation to special conditions. In brief, the first group may be called the "primitive group," and the second the "adaptive group." As was mentioned early in this paper, the absence of the compound eyes, which are present in the majority of trilobites, marks a larval stage in the ontogeny of higher forms corresponding with an adult condition in a large proportion of Cambrian genera and species. The phylogeny correlates so completely with the ontogeny that we can have no doubt that we have found the clue to the puzzling question of the meaning of blind trilobites.

Classification.

The following table shows these two divisions of blind trilobites :—

Group 1.—Primitive Forms.

	Range.
Agnostus (Brong.)	Cambrian—Ordovician.
Microdiscus (Emmons)	Cambrian.
Trinucleus (Lhwyd)	Ordovician.
Ampyx (Dalm.)	Ordovician—Silurian.
Dionide (Barr.)	Ordovician.
? *Salteria* (Wyv. Thomson)	Ordovician.
Endymionia (Billings)	Ordovician.
Tiresias (McCoy)	Ordovician.
Conocoryphe, s.str. (Corda)	Cambrian.
Ctenocephalus (Corda)	Cambrian.
Erinnys (Salter)	Cambrian.

[1] Undersokn. ofv. Siljans. Trilob. Svensk. Geol. Undersokn., ser. C, No. 66 (1884), p. 89.

[2] Callaway, Quart. Journ. Geol. Soc., vol. xxx (1874), p. 196 ; ibid., vol. xxxiii (1877), p. 252.

[3] Pal. Foss. Canada, vol. i (1862), p. 92.

[4] Die Silur. Etagen 1 and 2, 1882, p. 125.

	Range.
Carausia (Hicks)	Cambrian.
Dictyocephalites (Bergeron)	Cambrian.
Eryx (Angelin)	Cambrian.
Aneucanthus (Angelin)	Cambrian.
Anopocare (Angelin)	Cambrian.
? *Avalonia* (Walcott)	Cambrian.
? *Bathynotus* (Hall)	Cambrian.
? *Carmon* (Barr.)	Ordovician.
Holocephalina (Salter)	Cambrian.
? *Telephus* (Barr.)	Ordovician.
? *Dindymene* (Corda)	Ordovician.
Areia (Barr.)	Ordovician.
Placoparia (Corda)	Ordovician.
Prosopiscus (Salter)	?
Isocolus (Angelin)	Ordovician.
? *Typhloniscus* (Salter)	Lower Devonian ?
? *Cyphoniscus* (Salter)	Ordovician.
Conophrys (Callaway) { probably	... Ordovician.
Shumardia (Billings) { larval forms }	... Ordovician.

Note.—Special visual organs (eye-spots) are developed in the young of *Trinucleus* and in the Harpedidæ.

Group 2.—Adaptive Forms.

	Range.
Harpes benignensis, Barr.	E'tage D*d* 1.
Illænus Angelini, Holm	Trinucleus Beds.
——— *aratus*, Barr.	E'tage D*d* 1.
——— *cæcus*, Holm	Lyckholm Beds, Keisley Limestone, Kildare L.
——— *galeatus*, Reed	Keisley Limestone.
——— *Katzeri*, Barr.	E'tage D*d* 1.
——— *leptopleura*, Linnars.	Trinucleus Beds.
——— *Zeidleri*, Barr.	E'tage D*d* 5.
? *Proctus dormitans*, Richter	Tentaculites Beds.
? ——— *expansus*, Richter	Tentaculites Beds.
Acidaspis myops, Richter	Tentaculites Beds.
Phacops (*Trimerocephalus*) *lævis*, Münst. ...	Upper Devonian.

The genera *Dindymene*, *Typhloniscus*, and *Carmon*, which I have with some hesitation placed in Group 1, may have to be regarded as reversionary or degenerate types, on account of their primitive adult cephalic features, combined with general morphological characters which may be found to prove phylogenetic affinity with genera of high rank. But we are not at present able to definitely decide this point. The other genera in Group 1 which are marked with a query (*Salteria*, *Avalonia*, *Bathynotus*, *Telephus*, and *Cyphoniscus*) may be ultimately found to possess eyes.

Barrande[1] gave in 1872 a summary of the blind genera and species found in Bohemia, and incidentally noticed the foreign blind forms. The classification, however, which he adopted took no account of the phylogenetic principles which are now established, and therefore it is to a large extent artificial; but he recognized the fact that the blind forms fall into two natural groups, characterized by the presence or absence of facial sutures. On a comparison of the classification and enumeration in his table as given below with that which I have put forward, it will be perceived that a few additions

[1] Barrande, Syst. Sil. Boh., vol. i, p. 131; ibid., Suppl., vol. i, pp. 155–162.

have been made, and that some alterations have been necessitated by the revised nomenclature, such as in the case of *Conocephalites* and the elimination of the genus *Atops*, upon which I have commented above.

BARRANDE'S GROUP 1.—GENERA OF WHICH ALL THE KNOWN SPECIES ARE BLIND.

(*a*) GENERA RECORDED IN BOHEMIA.

Agnostus, Brong.
Ampyx, Dalm.
Areia, Barr.
Dindymene, Corda.
Dionide, Barr.
Placoparia, Corda.

(*b*) GENERA RECORDED IN FOREIGN COUNTRIES.

Acontheus (=*Aneucanthus*), Angel.
Anopocare, Angel.
Eryx, Angel.
Isocolus, Angel.
Atops, Emm.
Microdiscus, Emm.
Bathynotus, Hall.
Endymion, Bill.
Shumardia, Bill.
Typhloniscus, Salt.

GROUP 2.—GENERA OF WHICH ONLY SOME SPECIES ARE BLIND.

(*a*) GENERA RECORDED IN BOHEMIA.

Carmon, Barr.
Conocephalites, Zenk.
Harpes, Goldf.
Illænus, Dalm.
Telephus?, Barr.
Trinucleus, Lhwyd.

(*b*) GENUS RECORDED IN FOREIGN COUNTRIES.

Phacops, Emm.

Geological Distribution.

We must now consider the geological distribution of these blind forms. Barrande (loc. cit.) noticed that they were mostly confined to the "Lower Silurian," and in his summary (Suppl., vol. i, pp. 155–162) he brought out the facts of their distribution by means of ratios, showing that the largest proportion occurred in the "Primordial Fauna," amounting to ·296 of the whole number of species of trilobites in Étage C, i.e. eight species out of the twenty-seven recorded from it. In his "Second Fauna" the proportion was less, being only ·2 of the whole, i.e. 25 species out of 127; while in the "Third Fauna" only one out of the 205 species was known. The decrease in the relative abundance of blind forms is thus very marked as we rise in the stratigraphical succession. But out of the total number of blind species in Bohemia about three-fourths occur in the "Second Fauna."

If we now turn to the list I have given of blind forms, and confine our attention first to Group 1—the primitive forms—we shall see that their predominance in the Cambrian is plainly exemplified. Thus, omitting those genera which for various reasons stated above are doubtfully included in this group, or may possibly possess eyes or be immature forms, we find there are eleven genera occurring in the Cambrian, of which ten are peculiar to it and one ranges up into the Ordovician. Nine genera occur in the Ordovician, of which seven are peculiar and one ranges up into the Silurian. Only one genus is known from the Silurian, and this is a survivor from the Ordovician. In the Devonian there is only one, and that is doubtful. As Beecher[1] has shown in a diagram, the Hypoparia are more

[1] Amer. Journ. Sci., vol. iii (1897), p. 182.

numerous in the Cambrian than at later periods, and all the Cambrian blind genera belong to this order. In this formation the blind genera constitute also a much larger proportion of the whole trilobitic fauna than they do in higher Palæozoic beds. These facts indicate that the abundance of blind genera at this geological period marks a certain stage in the evolution of the Trilobites, and not necessarily the prevalence of certain conditions which induced as an adaptive modification the loss of eyes. In the Ordovician we notice that all the blind genera which do not belong to this Hypoparian type are the more or less morphologically primitive ancestors of the higher families, and still possess many features associated with the lower and earlier Cambrian forms. Larval characters are retained in the adult in spite of secondary specialization, and are accompanied by signs of progressive differentiation; as, for instance, in *Areia* and *Placoparia*. These primitive and ancestral genera have died out when we reach the Silurian, with the exception of one belated survivor. We no longer find the Hypoparia present in any force, and therefore these trilobites, belonging to the phylogenetic stage anterior to the evolution of compound eyes, are absent. All the blind forms which do occur belong to the higher families and genera, which normally possess well-developed eyes. Eyes have been lost in a few species for special reasons for which we have now to seek; and we cannot explain their absence on phylogenetic grounds.

Character of the Rocks.

The character of the rock in which blind genera and species belonging to both our groups have been found has received considerable attention at the hands of some palæontologists, and much importance has been attached to it. But since we have shown that all the genera in Group 1 owe their want of eyes to their phylogenetic position, and that the absence of these organs in their case cannot be interpreted as a secondary adaptive character, no question about the manner and materials of deposition apparently concerns them. This has not been always recognized, and indeed it is possible to argue that the persistence and survival of these blind genera of primitive organization were due to the existence of conditions under which eyes would have been of little or no use. For this reason we must look more closely into the character of the sediment which accumulated, the physical conditions which prevailed, and the fauna which flourished during the existence of the blind genera of our Group 1.

(*To be continued.*)

IV.—On Mr. W. Gunn's Correlation of the Carboniferous Rocks of England and Scotland.

By Wheelton Hind, M.D., B.S. Lond., F.R.C.S., F.G.S.

ALL students of Carboniferous geology will hail with pleasure Mr. W. Gunn's masterly paper in the August number of the Geological Magazine (p. 342), and it is only to be regretted that the publication of such important stratigraphical facts should have

been delayed for so long; but however useful from the numerous facts it contains, I must take exception to the deductions made from them. The paper is a remarkable one, because, while having for its object the correlation of rocks which occur over a wide expanse of country, no appeal has been made to palæontological evidence to clinch the author's views which are based on purely stratigraphical considerations.

The paper would have been so much more helpful, too, if Mr. Gunn had carried his table of correlations further south, and given his opinion as to the equivalents of the beds shown in his scheme to a typical section of the Carboniferous sequence in Derbyshire; for no correlation of Carboniferous rocks can be satisfactorily established without a consideration of the important Carboniferous sequence of the Midlands.

Mr. Gunn's hypothesis, briefly stated, is, that the Lower Scottish Limestones of the East of Scotland do not represent any part of the Mountain Limestone of Yorkshire, but are the equivalent of the upper part of the Yoredale Series of Phillips, and that the lower part of the Yoredale Series of Phillips and the Great Scar Limestone of Yorkshire are represented in Scotland by the Calciferous Sandstone Series.

Now it is an important fact that the fauna of the Mountain Limestone of Derbyshire and Yorkshire is identical with that of the whole of the Yoredale Series of Phillips and the Great Scar Limestone, and further, that the fauna of the Limestones of the East and West of Scotland is also characterized by the presence of the majority of the same forms; while, on the other hand, the fauna of the Calciferous Sandstone Series is very different indeed, containing only very few species, which go up into the Carboniferous Limestone Series.

I have attempted to show these palæontological results in a paper in the Geological Magazine of February, 1898, and have based a table on them for the correlation of the British Carboniferous rocks, which is very different from that now given by Mr. Gunn; and I believe the recognition that the Yoredale Series of Phillips is nothing more than the upper part of the Carboniferous Limestone of Yorkshire and Derbyshire, which has been split up by wedges of shale and sandstone coming in from the north, to be the key of the problem, a view which the identity of the faunas proves to be almost certain.

A mere consideration of the thickness of the various series of strata tends to the same conclusion. What has happened that the mass of limestone in South Yorkshire is from 2,000 to 3,000 feet thick, while at Ingleborough, a distance of about 20 miles, its supposed representative, the Great Scar Limestone, is only 500 feet thick? What, again, are the representatives in Lower Wharfdale of the 1,000 feet of Yoredale beds in Wensleydale with seven thick beds of limestone?

My contention that the Carboniferous Limestone splits up as it passes north, forming more and more beds of limestones on its way, some of which, however, do not extend as far as others, is splendidly

illustrated in Mr. Gunn's scheme, and is based on the most complete palæontological and stratigraphical evidence; and these views have been published at length in the GEOLOGICAL MAGAZINE, Decade IV, Vol. IV (1897), pp. 159, 205; Decade IV, Vol. V, p. 61. The Calciferous Sandstone Series, as Mr. Gunn points out, "mainly a fresh-water deposit," is probably almost unrepresented in the Midlands. We know that at Thornton Force, below Ingleborough, only a very few feet of conglomerate exist below the base of the Scar Limestone; and it is surely a normal state of things that a fresh-water deposit cannot have actual homotaxial equivalents, of wide extent, though, of course, marine and fresh-water beds have been deposited at the same moment in different parts of an area, and may therefore be said to be contemporaneous. If Mr. Gunn simply means to use the term equivalents in a sense of time, of course it is quite possible that, while some of the beds of the Calciferous Sandstone were being laid down in the north, a deposit of limestone was going on further south, just as that deposit must have been going on while terrestrial conditions obtained in the north, as shown by the various beds of coal. The Yoredale Series are, however, the real homotaxial and contemporaneous equivalents of the upper part of the Carboniferous Limestone.

The Yoredale type of rocks must have been very local, and seems not to have extended very far west, for the Furness and Shap districts show massive limestones of great thickness quite undivided, and their southern limit appears to be about a line joining Settle with Pateley Bridge, south of which the limestone is quite undivided.

The differences in the Carboniferous succession are due entirely to the conditions of deposit, land being not far away to the north and north-west, so that in the Scottish area, littoral, fresh-water, and terrestrial conditions obtained to a large extent, being replaced by marine beds when the land sank more rapidly, while further south a continuous unbroken deposit of limestone was being laid down.

In order to establish Mr. Gunn's table of equivalence, it will be necessary for him to show a fauna characteristic of the Yoredale Series of Phillips, and to be able to subdivide this fauna into upper and lower and to trace its extension into Scotland, for up to the present there is not a single fossil that can be said to be characteristic of the series. It would afford some ground, too, for accurate classification if it could be established that any of the limestones themselves possessed a distinctive fauna; otherwise, however simple it may look in a tabular scheme, the identification of any one bed in a column with one in another is purely theoretical, for different results would be arrived at if a datum-line were taken at the top instead of at the bottom. For example, the Hardraw Scar Limestone is the fifth limestone below the Millstone Grit at Ingleborough: why should it not be the fifth below the Millstone Grit at Wensleydale, or in Northumberland? In fact, correlation without palæontological evidence is absolutely of no value.

V.—On the Age and Origin of the Granite of Dartmoor, and its Relations to the adjoining Strata.

By Alex Somervail.[1]

THE object of this paper is an attempt to furnish proof of what has been a growing conviction in the mind of the writer, that the true age of the Dartmoor granite, and probably its associated line of bosses running south-westwards into Cornwall, might be referable to an interval or period of geological time between the Lower and the Upper Culm, or Carboniferous system.

Up to the present time, as geologists are doubtless well aware, these granite bosses have been considered Post-Carboniferous and Pre-Triassic as to age, and the evidences for this so ably advanced by De la Beche and others have been almost universally accepted. Up to Lower Culm, or Carboniferous times, the nature of the proofs have been of so decisive and convincing a kind as to place the question beyond doubt to the minds of most observers. There are, however, grave doubts and difficulties with regard to the Permian age of the granite. There are no clear proofs that it even belongs to an early portion of that formation; or that it can in any way be connected with the highly basic lavas of the adjoining Permian strata; indeed, the evidences for the very reverse of this is the case.

In support of this contention the writer would draw attention to a point which has never before been urged, which appears to him to very materially affect the question as to the true age, not only of the granite of Dartmoor, but also of the other bosses of the same rock already referred to.

In the history of the Culm rocks of South Devon there is what he considers to be a striking gap or break in the sequence between the Lower and the Upper Culm, which without doubt would indicate a prolonged interval of time between these two members of the system, as will immediately appear.

In making use of the term Upper Culm he would refer more especially to certain conglomerates, grits, and sandstones, which seem only to have a very local development in South Devon. They occur as mere isolated or semi-detached deposits confined to a very limited area in the neighbourhood around Newton Abbot as a centre. The most conspicuous of these deposits are certain conglomerates — coarse, medium, and fine — associated with which are grits and sandstones. These conglomerates are not met with in any of the other extensive general sections where the Lower Culm beds occur, as in the direction of Exeter and the Teign Valley .Neither are they known to occur in the North of Devon. In point of fact these conglomerates show every indication of belonging to a much higher series of beds than any that are elsewhere developed in other portions of the county.

There is a striking lithological contrast presented between this conglomerate series and all the other older members of the Culm in their relations to the granite. The older members are everywhere affected by great earth-movements, bent and plicated sometimes to an

[1] Read before Section C (Geology), British Association, September, 1898.

extraordinary degree. There is likewise a cleavage structure more or less developed throughout these rocks. With regard to the conglomerate series, the very reverse of all this is the case, and as a rule they repose at low angles and seem to have suffered little disturbance in comparison with the older members of the Culm.

The Lower Culm system has lately received close attention from Messrs. Hinde & Fox in their valuable memoir recently published in the Quart. Journ. Geol. Soc.[1] The Radiolarian cherts and associated beds there described are conclusively shown to have been deposited in a sea of great depth, far removed from the detrital washings of the land; yet there is the clearest of evidence that this deep-sea bottom was elevated by earth-crust-movements, and even ultimately eroded and wasted, to supply the materials which abundantly occur in the conglomerates just referred to. These conglomerates, in all the various localities where they occur, contain abundant fragments of the Radiolarian cherts, besides those of the other associated rocks of the Lower Culm series.

It has been suggested that the fragments of the Radiolarian cherts may have been brought up to the surface by volcanic explosions. These fragments, however, are as a rule well rounded and water-worn, and they are not accompanied by any true tuff-like matter in the conglomerates. The only intelligible explanation of the fragments of the cherts in the contents of the conglomerates is the long interval separating the former from the latter; the granting of sufficient time to account for the phenomena of elevation, waste, and reconstruction.

It is most interesting at this point, to note that during the formation and elevation of the Lower Culm there are the clearest proofs of contemporaneous volcanic action. Belonging strictly to this period, there are in the immediate localities concerned numerous examples of eruptive, explosive, and effusive volcanic products, which might have extended over a long period previous to the formation of the conglomerate series. These volcanic outbursts had apparently entirely ceased long before the formation of the conglomerates began to be deposited. It is to the latter portion of this interval—sufficiently long—that the writer would refer the eruption of the Dartmoor granite.

On studying with attention the geological map of the area, it will be perceived that during the early or Lower Culm period the central area of Dartmoor had been long weakened by the extensive volcanic action previously referred to. Volcanic rocks, principally eruptives, are thickly clustered together on each side of what is now the granite—as at Tavistock on the west and in the Teign Valley district on the east side,—running along a line of old pre-granitic fissures. All these volcanic rocks are decidedly Lower Culm in age, but older than the associated granite, as the latter truncates and indurates them.

The central portion of the area of Dartmoor, now occupied by the granite, was clearly a previous centre of volcanic activity

[1] Vol. li (1895), p. 609.

both in Devonian and in Lower Culm times. In the vicinity of the other granitic bosses volcanic action was also active throughout Devonian times, and continued for long periods in these and other parts of the counties of Cornwall and Devon to produce highly basic products; culminating during the Lower Culm period in Devonshire in those very extensive basic products extending in a line through what is now Central Dartmoor.

These long-continued, highly basic products, however, at length came to a close, possibly from sheer exhaustion, and seem to have been followed by the highly acid products which now form the granites of Dartmoor and Cornwall.

Some of the views suggested in this paper occurred to the writer when in Central France, sitting on the basic products of the Puy de Parion, gazing at the trachyte mass of the Puy de Dôme. That enormous mountain of domite, as it is termed, with others in the same chain of puys, together with masses of trachyte elsewhere, if one could exactly explain their history, might throw much light on the granite bosses of Dartmoor. In the case of the Puy de Dôme and other trachyte puys, there are good reasons for regarding these acid protrusions as later than the basic ones, as there are also for the acid magma which now forms our own Dartmoor granite. The Dartmoor granite, though now essentially a portion of a once deeply-seated core, was doubtless formerly represented in its upper and outer portions by a variety of materials—necessarily arising from loss of heat, pressure, and more rapid cooling—of a more trachytitic nature. The boss of granite as it now remains has had stripped from it its more external parts. This even seems true of the Puy de Dôme itself, and other trachyte masses like those of the Rhine district, which certainly have suffered a considerable amount of denudation within the very limited period since their formation.

The question might now be asked—Is the interval between the Lower Culm and the overlying conglomerates, with the included fragments of the former, sufficiently great to allow for the formation or protrusion of the granite? The author is firmly convinced that it is, for the reasons already given. Messrs. Hinde & Fox, in their paper already referred to, say: "It is hardly probable that the Radiolarian beds are directly succeeded by beds of coarse clastic materials, i.e. the Ugbrooke Park conglomerates." The author's own personal observation of these conglomerates impresses him with the fact of their being widely separated in time from the chert series. In addition to the reasons already mentioned, the conglomerate series never seem to occur in direct succession above the lower members of the Culm. They rather seem to rest on their denuded and disturbed surfaces, and many appearances would indicate that the conglomerate series overlap, or are unconformable on the Lower Culm. Indeed, the conglomerate series sometimes rest directly on the Devonian limestones, clearly proving that great denudation of the Lower Culm, and even of the Devonian itself, had occurred previous to the formation of the conglomerates. These unconformabilities were long ago distinctly noted by Godwin-Austen

and De la Beche,[1] as was also the fact of the conglomerates containing fragments of the cherts and other Lower Culm rocks. As to the age of these conglomerates, the author thinks they might, for good reasons, be referred to the Pennant Grit series of the South Wales and Bristol Coalfields, both of which, curiously enough, contain boulders or pebbles of coal and anthracite from the lower measures, indicating similar conditions to what existed in South Devon.

The question of the time required during this interval or break in the sequence between the Lower and Upper Culm deposits, for the protrusion of the granite, is now sufficiently well disposed of. So also is the question of the protrusion of the granite following the old and weakened line of former Culm basic products. There is, moreover, much good reason to suppose that the acid magma of the granite, and its perhaps more trachyte-like external portions, followed very hard after the great basic masses already mentioned.

The most important question of all, however, remains to be answered — Do the contents of the conglomerates contain any materials such as might be derived from the waste of granitic or trachyte-like rocks? To the eye, and with the aid of a lens, these conglomerates, besides the chert fragments, contain much arkose materials, such as quartz, felspars, etc.; and mica in large flakes are most abundant in them. These granitic and trachyte-like materials are present in such large quantities as would make it very difficult to find their source of origin from the wear and tear of any other of the ordinary Devonian or Lower Culm rocks. The felspar crystals and particles are so abundant, so large, and so distinct that the author deemed it quite unnecessary to have specimens submitted for microscopical examination. Fragments of a variety of granite are also present.

With regard to the alleged fragments of the Dartmoor granite said to have been found in the adjoining Permian breccias by the late Mr. Pengelly [2] and others, the writer would remark that if this be really so it would accord very much better with the inter- or late Culm age of that rock than with its Permian or Pre-Triassic age, as formerly held.

In the breccias referred to the author has been able to detect many examples and varieties of a kind of quartz-porphyry. These latter might in some way or other be connected with the outer granite mass of Dartmoor, as also might be the large and numerous crystals of Murchisonite found in the breccias, which seem to have no connection with the subsequent basic flows in that formation.

It is rather unfortunate that none of these Upper Culm rocks or conglomerates are found in connection with the other bosses of granite running into Cornwall, whereby we might better test their age; but many reasons combine to show that they all belong to the same period of protrusion.

There are many other points, such as the denudation of the Devonian

[1] Trans. Geol. Soc., ser. II, vol. vi, p. 457; Geol. Rep. of Cornwall, Devon, etc., p. 111.

[2] Rep. Brit. Assoc., 1861, p. 127.

and Lower Culm strata from portions of the granitic areas in question, but these must be dealt with subsequently. There is, however, one important point to which the writer desires to draw attention—that is, the almost certain fact that the Devonian and Lower Culm strata had been previously disturbed and folded by great earth-crust-movements before the protrusion of the granite. The arrangement and disposition of the strata in relation to the granite certainly favour this conclusion. The great plications and the cleavage of the strata had at least in greater part, if not in whole, been completed before the eruption of the granite had taken place, and also before the conglomerate series of South Devon had been deposited, which latter occurrence, however, the author believes was subsequent to the eruption of the granite. It is extremely probable that these highly acid cores which now represent the granite never were the stumps or roots of great volcanic cones, in the correct sense of the term, as suggested by the late Mr. R. N. Worth,[1] from which proceeded highly basic lavas, but rather that they were the feeders or more central portions of extrusions, parts of which came to the surface as trachyte, forming great dome-like masses after the manner of the Puy de Dôme, near Clermont Ferrand, in Central France.

In conclusion, the author is aware that the evidences here brought forward to sustain his views as to the age and origin of the granite of Dartmoor are not absolutely conclusive; but when compared with the opinions already held they seem at all events worthy of consideration and discussion.

NOTICES OF MEMOIRS.

I.—Neue Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura und der Kreide, von Dr. Rüst. Palæontographica, Band xlv (1898). 4to; pp. 67, pls. i–xix.

New Contributions to the Knowledge of the Fossil Radiolaria from the Jurassic and Cretaceous Rocks. By Dr. Rüst.

SINCE the completion of his important work on the Palæozoic Radiolaria, Dr. Rüst has been revising his earlier monographs on those from the Jurassic and Cretaceous strata. Struck by the close resemblance of the forms in the Upper Jurassic Aptychus-beds of Cittiglio, near Laveno, from which 79 new species were described and figured by Professor Parona[2] some years since, to those which he himself[3] had described from the Lower Neocomian beds at Gardenazza near St. Cassian, the Aptychus shales near Urschlau, and from Kren, and the Tithonian jaspers of the Tyrol and West Switzerland, Dr. Rüst prepared some hundreds of microscopic sections of the nodules of siliceous limestone from Cittiglio, and in these he has discovered no fewer than 212 new species, which, with

[1] Quart. Journ. Geol. Soc., vol. xlv, p. 398, etc.
[2] Bollettino della Soc. geol. italiana, vol. ix, fasc. 1 (1890).
[3] Palæontographica, Bd. xxxi (1885); Bd. xxxiv (1887–8).

some few other new forms from Gardenazza, and from the Lias Coprolites of Ilsede, are fully described and figured in the 19 plates accompanying this monograph. A comparison of the species from the various localities mentioned above leads the author to consider that they belong to one and the same Radiolarian fauna. The only new genus proposed, *Cyclastrum*, is included in the family Porodiscida. A distinguishing feature of the Cittiglio Radiolaria is the large number of forms of the Order Cyrtoidea; some of them, moreover, are of unusually large size—one specimen of *Stichocapse Umberti*, measuring 1·152 mm. by 0·16 mm. in length and breadth, exceeds in size any fossil form of the group hitherto known. Though the siliceous tests in these organisms are now for the most part replaced by pyrites and marcasite, their structural details have been very perfectly preserved, and they can be determined with as much precision as recent specimens.

Thanks to this new contribution of Dr. Rüst, taken in connection with his earlier work and that of Professor Parona, we are now furnished with a fairly satisfactory standard of reference as to the character of the Radiolarian fauna of the summit of the Jurassic and the base of the Cretaceous rocks in the Tyrol, Bavaria, and Northern Italy. G. J. H.

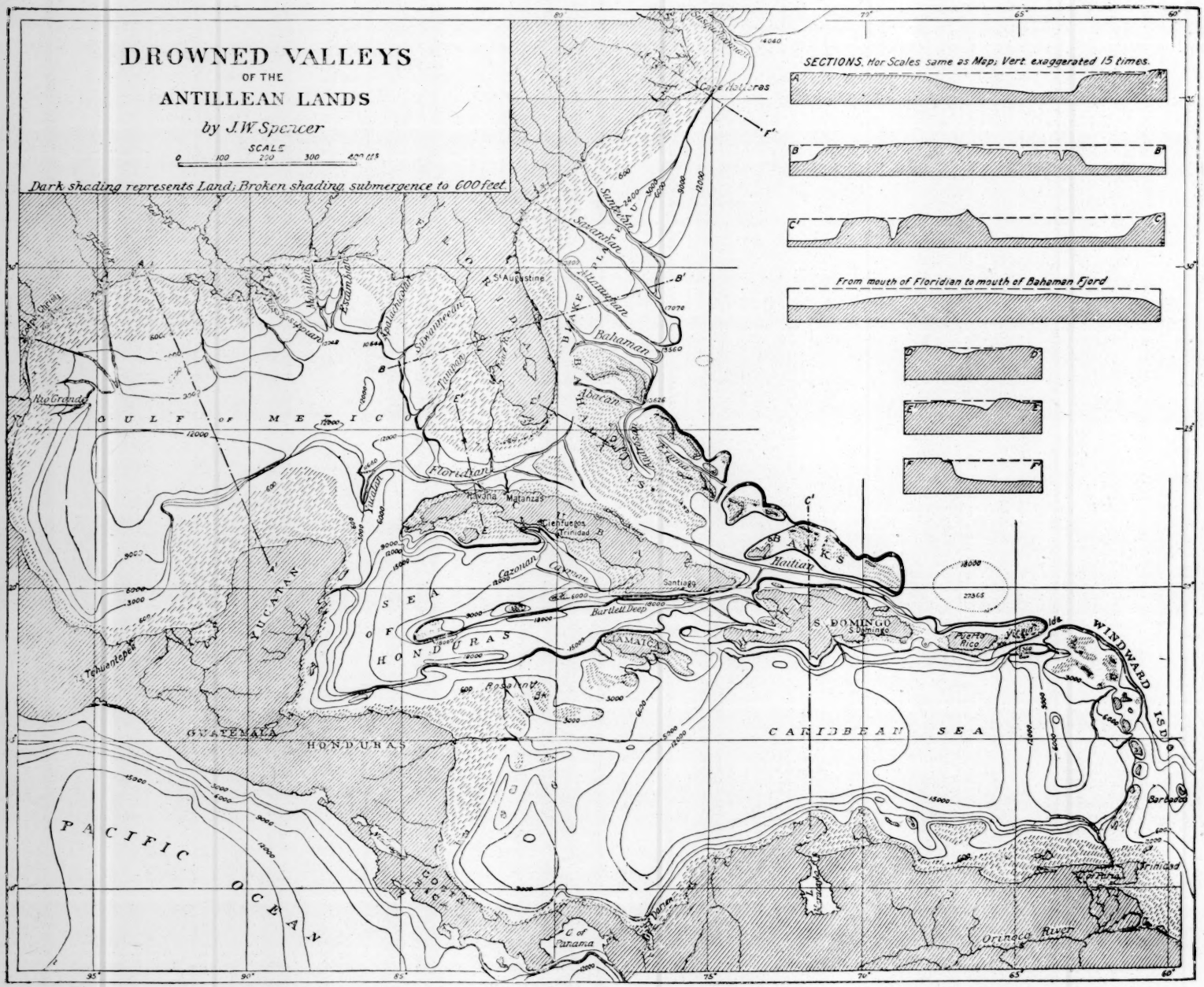
II.—Resemblances between the Declivities of High Plateaux and those of Submarine Antillean Valleys. By J. W. Spencer. (Transactions of the Canadian Institute, vol. v, 1898, pp. 359–368.)

[Communicated by Professor E. Hull, F.R.S.]

THIS paper is a sequel to the "Reconstruction of the Antillean Continent,"[1] as in it the analysis of the slopes of the drowned valleys had not been considered. Both in the land and in the submarine valleys their gradients are of two kinds: (1) Those of rivers which are flowing over continental plains, or upon the surface of high tablelands, where the declivities of the streams are so gentle as to be often reduced to even a foot per mile; (2) where the valleys are descending from higher to lower plateaux, in which case the descent is over a series of precipitous steps, separated by short gradation planes, marking pauses in the elevation of the land. Thus, if the mean descent of such a valley be taken, an average gradient would be entirely misleading. While the mean slope may reach from 100 to 200 feet per mile, it is found that in reality it is composed of perhaps twenty abrupt steps with almost level flats between. Of the steps may reach a height of five hundred feet or more. Such features are seen descending from the Mexican plateaux (of 8,000 feet in altitude) to the Gulf of Mexico. The valleys end abruptly in amphitheatres indenting the floors of the tablelands and dissecting them.

In the drowned Antillean valleys long reaches have been discovered with slopes of only a foot per mile like that of the

[1] Bull. Geol. Soc. Amer., vol. vii (1894), pp. 103–140.



To illustrate Dr. J. W. Spencer's Paper on Changes of Level in Jamaica, p. 515.

Mississippi, or of some plateau valley. These are separated by abrupt steps similar to the succession of those descending from the margins of the Mexican tablelands. This point of analogy between the drowned and land valleys, as well as the occurrence of short amphitheatres indenting the edges of the submarine plateaux, when carefully compared, very greatly strengthens the conclusions drawn in the "Reconstruction of the Antillean Continent," namely, that the valleys traversing the submarine Antillean plateaux were of land origin, and indicate the depth to which the West Indian Continent has sunk, even to a depth of two miles or more.

III.—Late Formations and Great Changes of Level in Jamaica. By J. W. Spencer. (Transactions of the Canadian Institute, vol. v, 1898, pp. 324–357.)

[Communicated by Professor E. Hull, F.R.S.]

(PLATE XVIII.)

THIS paper is descriptive of the physical features of Jamaica which bear upon the evidence of great changes of level in late geological times, and extends the conclusions set forth in the author's work upon the "Reconstruction of the Antillean Continent."[1]

Speaking in a broad way, Jamaica is a dissected tableland, surmounting another but submarine plateau, extending from Haiti to the Yucatan banks, now submerged to depths of 3,000 to 4,000 feet. These banks have the form of old base planes of erosion, but they are traversed by deep valleys more than 2,000 feet below the summit of the platform. Even within the limit of the submarine plateau mass the channels reach to a depth of 9,600 feet, or more than 5,000 feet below the surface of the drowned plains. Here, as everywhere, when studied, the valleys have in all respects the features of those of the plateau regions of Mexico and other countries. And they head in embayments of the land, receiving as tributaries the principal rivers of the district.

The modern topographic features of Jamaica date back practically only to the middle Miocene period, for the larger part of the island is covered by old Miocene white limestones. But the subsequent denudation has been enormous, for although the formation still reaches a thickness of 2,000 feet in some places, yet in others the dissection of it has penetrated the whole mass. Upon this old Miocene surface no Mio-Pliocene formations occur, until those at the close of the period, showing it to have been one of long-continued elevation.

Upon these white limestones there was a subsequent mechanical deposit of marls with pebbles (made up in part of older fragments), and in other localities there were gravels and loams (according to the source of the materials). These accumulations rise to a height of 500 feet in stratified beds, still nearly horizontal, in contrast to the upturned beds of the underlying white limestone. They contain

[1] Bull. Geol. Soc. Amer., vol. vii (1894), pp. 103–140.

a few shells of modern species. The formations have been found to correspond, in position, with the Lafayette of the continent or the Matanzas of Cuba, which have been provisionally placed at the close of the Pliocene period.

Overlying the Layton beds, where these have not been removed and other strata formed near the surface of the country, there has been a mantle of stratified loams and gravels laid down. This occurs up to an elevation of 600 feet. It has been named the Liguanea formation, and has been correlated with the Columbia of the continent and the Zapata of Cuba. While no fossils have been found in this fragmental deposit, yet its stratified beds, occurring adjacent to the coast, high above the sea, indicate its origin at sea-level. Thus it appears that the island was submerged to 500 or 600 feet during two distinct epochs since the Mio-Pliocene period.

The paper describes the broad undulating features characterizing the Mio-Pliocene period. These have since been dissected by wide and deep valleys, extending from the land to the submerged plateau formed subsequent to the Layton epoch; and from the depths to which they reach in the submerged plateau the inference drawn is that the land stood more than 10,000 feet higher in the early Pleistocene period than to-day. The Layton formation during this elevation was enormously degraded, so that in many localities only remnants are found in protected places. Jamaica affords a favourable region for studying the contrast between the undulating topography developed near base-level of erosion during the Mio-Pliocene period of more extensive lands than to-day, and the great and enormously deep valleys of the post-Layton or early Pleistocene epoch. The moulding of the submarine plateau is supposed to have occurred during the Mio-Pliocene period, while the deeply drowned valleys are continuations of those of the land which are of post-Layton age.

In contrast with these two features of erosion, that of the post-Liguanea epoch of submergence has been of small proportions; indeed, the post-Liguanea elevation is so recent that it has not passed beyond the stage of making narrow deep cañons. On account of this formation overlying the remains of the Layton series, the different features of erosion up to an altitude of 600 feet are geologically preserved, while at greater altitudes they are not so easily distinguishable from those produced before the Liguanea epoch; yet when one has become familiar with the features of erosion, the respective epochs are generally recognizable. The post-Liguanea cañon-making epoch was characterized by an elevation of 150 to 200 feet more than at present, for the continuations of the existing rivers are traceable to that depth across the submerged coastal plains. The subsidence which caused the drowning of these valleys reached to an elevation of 10 to 25 feet below the present level; since which time the coral reefs of the coast have emerged to this amount.

Numerous as these oscillations appear, all of them, since the post-Layton elevation, have been of comparatively small and diminishing proportions. These changes of level of land and

sea have occurred on the other West Indian islands and on the continent; and, from the amount of work accomplished, the Pleistocene period seems to have been one of long duration.

Outside of Jamaica the geological features of that beautiful island would not be of special interest, except that here we find additional evidence, both upon land and in the adjacent sea, supporting the theory of the high continental conditions of the West Indian region in the early Pleistocene period, when the land stood more than two miles above the present altitude, uniting North and South America, as is set forth in the "Reconstruction of the Antillean Continent."

IV.—British Association for the Advancement of Science. Sixty-eighth Annual Meeting, held at Bristol, September 8–13, 1898.

List of Papers read in Section C, Geology.

W. H. Hudleston, M.A., F.R.S., F.L.S., F.C.S., F.G.S., President.

The President's Address. (See Geol. Mag., p. 458.)

Professor C. Lloyd Morgan.—Some Notes on Local Geology.

E. B. Wethered.—On the Building of Clifton Rocks.

A. Strahan.—The Revision of South Wales and Monmouthshire by the Geological Survey. (See Geol. Mag., p. 488.)

H. Bolton.—The Exploration of two Caves at Uphill, Weston-super-Mare, containing remains of Pleistocene Mammalia (*by the late E. Wilson*).

Thomas H. Holland.—The Comparative Actions of Subaërial and Submarine Agents in Rock Decomposition.

H. B. Woodward.—On Arborescent Carboniferous Limestone from near Bristol.

Report of the Committee for collecting Photographs of Geological Interest in Britain.

Report of the Committee for collecting Photographs of Geological Interest in Canada.

Professor O. C. Marsh.—The comparative value of different kinds of fossils in determining Geological Age.

Professor J. F. Blake.—Aggregate Deposits and their relations to Zones. (See Geol. Mag., p. 481.)

T. Groom.—The Geological Structure of the Malvern and Abberley Ranges.

——— The Age of the Malvern and Abberley Ranges.

J. R. Dakyns.—The probable Source of the Upper Felsitic Lava of Snowdon.

E. Greenly.—On the occurrence of Arenig Shales beneath the Carboniferous Rocks at the Menai Bridge.

——— On an Uplift of Boulders at Llandegfan, Menai Straits.

W. L. Addison.—On the Comparative Dimensions of some Atoms.

L. J. Spencer.—Leadhillite in ancient Lead Slags from the Mendi Hills.

——— Supplementary List of British Minerals.

A. Somervail.—On the Age and Origin of the Granite of Dartmoo and its Relations to the adjoining Strata. (See GEOL. MAG p. 509.)

Professor T. Rupert Jones.—Report of the Committee on Fossi Phyllopoda.

E. J. Garwood.—Report of the Committee on Life-Zones in th British Carboniferous Rocks.

R. Etheridge, F.R.S.—On the Relation and Extension of the Franco Belgian Coalfield to that of Kent and Somerset.

Dr. Marsden Manson.—On the Laws of Climatic Evolution.

Professor E. Hull, F.R.S.—On the Sub-oceanic Physical Features o the North Atlantic.

W. H. Hudleston, F.R.S.—On the Eastern Margin of the Nort Atlantic Basin.

R. D. Oldham.—The Great Earthquake of 1897.

Professor A. P. Coleman.—Report of the Committee on the Flora an Fauna of the Interglacial Beds in Canada.

J. Lomas.—On Worked Flints from Glacial Deposits of Cheshire an the Isle of Man.

E. Greenly and *A. B. Badger.*—The Glacial Sections at Moel Tryfae

C. W. Andrews.—On some Dinosaurian Remains from the Oxfor Clay of Northampton.

Professor H. F. Osborn.—Restoration by Charles Knight of th Extinct Vertebrates—*Brontosaurus, Phenacodus, Coryphodon Teleoceras.*

E. Wethered.—The Work of Encrusting Organisms in the formatio of Limestone.

W. H. Wheeler.—The Action of Waves and Tides on the Movemen of Material on the Sea Coast.

Rev. G. C. H. Pollen.—Further Exploration of the Ty Newyd Caves, Tremeirchion, N. Wales.

T. Plunkett.—Further Exploration of the Fermanagh Caves.

P. C. Kermode.—Report of the Committee on the Remains of th Irish Elk in the Isle of Man.

Report of the Committee on the Erratic Blocks of the British Isles

Professor J. Milne, F.R.S.—Report of the Committee for Seismo logical Investigation.

Report of the Committee on the Fauna of Caves near Singapore.

Report of the Committee on the Structure of a Coral Reef.

M. Laurie.—Final report on the Eurypterids of the Pentlands.

Papers bearing on Geology read in other Sections :

Professor O. C. Marsh.—On the Families of Sauropodous Dinosauria

F. A. Bather.—On the Classification of the Pelmatozoa.

C. W. Andrews.—On Christmas Island.

REVIEWS.

I.—List of the Types and Figured Specimens of Fossil Cephalopoda in the British Museum (Natural History). By G. C. Crick, F.G.S., etc. 8vo; pp. 103. (London, 1898; printed by order of the Trustees of the Museum.)

THE great utility to specialists of such lists as this cannot be overestimated, and we are glad to be able to call favourable attention to the latest of an increasing series. It is to be hoped that the Museums Association will use their best endeavours to persuade the various institutions represented amongst their members to respond to the invitation of the British Association and proclaim their treasures in like manner, as indeed some of them both have done and are doing.

The object of the present list is to place permanently on record all the types and figured specimens, both British and foreign, of Fossil Cephalopoda preserved in the Geological Department of the British Museum.

Each specimen is entered under the name given to it when it was first figured or described, any names subsequently applied being appended in chronological order; whilst cross references are given from these last in the alphabetical order in which the whole is arranged. Each name is followed by an abbreviated reference to the work in which it occurs; while the formation and locality of the specimen, with its registered number in the collection, are given at the close of every main entry.

We are heartily glad to observe that corresponding lists of other groups of Invertebrata in the Museum are to follow; and though for the present the student is referred to the catalogues already published for the Vertebrata, it is to be hoped that the Trustees will ultimately see their way to issuing similar lists of these also, since much valuable time is wasted in hunting for the record of some desired type in a voluminous catalogue, where it has to be sought in its systematic position and possibly under some other name than the one it bore when described.

In the production of the present list full measure of praise must be awarded to all concerned in its production: even the printer appears at his best.

II.—On the Muscular Attachment of the Animal to its Shell in some Fossil Cephalopoda (Ammonoidea). By G. C. Crick, F.G.S., F.Z.S., etc. (Trans. Linn. Soc. London, ser. II, vol. vii, pt. 4, pp. 71–113, pls. xvii–xx.)

THE true relationship of the Ammonoidea to other Cephalopoda has long been a moot question, and there have not been wanting those, and that quite recently, who, fascinated by the external resemblance of some ammonite shells to that of *Argonauta*, have advocated the placing of the ammonite with the Dibranchiata. The interesting discovery by Mr. Crick, however, of the impression of the shell muscles and annulus proves the permanent attachment of the Ammonoid animal to its shell, and consequently its wide

separation from *Argonauta*, whilst it further establishes a point of resemblance in this respect between the Ammonoidea and the Nautiloidea.

The previous literature is scanty. Oppel (1863) figured part of the muscular attachment in *Ammonites steraspis*, but did not apparently even guess its significance. Trautschold in 1870 figured what he considered to be the impression of the muscular attachment in *Ammonites bicurvatus*. In 1871 Waagen accepted Oppel's figures as indicating a trace of the annulus, and diagrammatically completed what he considered to be the form of the shell muscle, which he believed was attached to the inner (umbilical) portion of the lateral area of the whorl. In this he appears to have been correct, though *Ammonites steraspis* proves to be an exceptional form. In the majority of the Ammonoidea the shell muscles were attached to the dorsal portion of the shell: they frequently either met or approximated each other in the median line of the shells, and in the latter case were united by a more or less narrow band corresponding to the dorsal portion of the annulus in the recent Nautilus. They were similarly connected round the ventral side by the annulus, so that an air-tight band fastening the mantle to the shell encircled the animal. Once detected, these scars prove fairly common, and there appears to be some ground for believing that their varying form in the different genera is in part due to the shape of the transverse section of the whorl and to the length of the body-chamber, but also, possibly, to other causes. They will probably ultimately afford important characters for the purposes of classification.

Mr. Crick describes and figures the principal forms detected in twenty-eight different genera. He is heartily to be congratulated on the production of this admirable monograph, and the Linnean Society on having published it in worthy form and with adequate illustrations, in which respect they put to shame a younger Society whose complaint is that it cannot get good palæontological papers. What is wanted now is a companion paper summarizing our knowledge of the muscular scars in the Nautiloidea.

III.—Geology for Beginners. By Professor W. W. Watts, M.A., F.G.S. 8vo; pp. xvii, 352. (London: Macmillan & Co., 1898. Price 2*s.* 6*d.*)

THE student who nowadays wishes to become a geologist, and is desirous not merely to learn the facts but to aid in advancing knowledge, must labour long and seriously. The general knowledge of rocks and fossils which seemed to form a sufficient basis twenty or thirty years ago, must now be supplanted by a more precise acquaintance with the characters of the principal rock-forming minerals and of the principal forms of life whose remains are found embedded in the strata. The young student should be able to recognize in microscopic slides the minerals and structures exhibited by such rocks as granite and basalt, quartzite, statuary marble, and oolite. Precision of knowledge in the beginning is the surest foundation for subsequent success. In the present work

the author aims to teach all that is required for the elementary stage of the Science and Art Examination, and for the examinations of the Oxford and Cambridge Schools' Examination Board. He places before his readers a concise account of all the principal facts and phenomena relating to geology, admirably arranged and expressed. At the end of each chapter is a recapitulation, and this is followed by a series of questions given at different times at the examinations before mentioned.

The work is illustrated by three hundred and ten excellent photographic views of rock-scenery and structure, and diagrams of geological sections and fossils. The descriptions of rocks and minerals, of rock-structures and earth-movements, of denudation and rock-building, leave little or nothing to be desired. Something might have been added to the description of 'subsoil' (p. 47) in reference to soft strata such as sand, gravel, or clay where the subsoil is practically the actual formation or rock. Such instances differ from the illustration relating to freestones where there is an intermediate weathered portion of rock or rubble, between the soil and the undisturbed rock. Opinions will differ with regard to the definitions of loam and grit on p. 135, but it is idle to call attention to such matters when the entire work bears evidence of most careful observation and research, and brings clearly before the student the latest information on all important subjects. A good general account of the leading fossils is given, and the methods of classification are popularly explained. This part of the subject is followed by a review of the principles of Historical Geology, and then each System is described. Taking the Ordovician System, the subject is treated under the headings of *Name, Subdivisions, Volcanic Rocks, Fossils, Economics and Landscape,* and *Conditions of Formation.* Evidently the author leaves for advanced students particulars of the characteristic fossils of the subdivisions. The Origin of Landscape and Economic Geology are the subjects of the last two chapters, and there is an excellent index. We have no hesitation in commending this little work to all beginners desirous of obtaining a sound and thorough introduction to geology; and we heartily congratulate the author on the accomplishment of his useful task.

IV.—Applied Geology. Part I. By J. V. Elsden, B.Sc. (Lond.). 8vo; pp. 96. (London: "The Quarry" Publishing Co., 5, Arundel Street, Strand, W.C., 1898. Price 5*s.*)

NO doubt there is need of a good general work on Applied Geology, as the excellent little treatises by Ansted & Page do not represent the present state of knowledge. A work professing to deal with all branches of applied geology must treat of them either in a very abridged form, as in the case of Page's Economic Geology, or in a series of volumes, and no single individual can possess intimate knowledge sufficient to justify his dealing fully with the subjects of water-supply, coal-mining, metal-mining, building-stones, etc. We are rather at a loss to know how to criticize the present part of Mr. Elsden's treatise, because in his preface he tells us "that these preliminary chapters scarcely give

an adequate idea of the scope of the completed work." At the outset we are surprised that a sum of five shillings should be charged for so comparatively meagre a volume. We judge that the whole of it is reprinted from the *Quarry* newspaper, in whose pages "the latter portion is still appearing"; and the information now given relates chiefly to geological surveying, to dips, outcrops and faults, to unconformities and overlaps, and other matters. These are well illustrated with diagrams, many of them being after the style of Sopwith's famous models. A good deal of space is occupied with mathematical calculations having reference to the determination of the true dip, and to the throw of faults and dislocated veins: information of questionable value to the practical man. A final chapter of twenty pages deals generally with the economic minerals which occur as stratified ore-deposits. As already stated it is not possible to judge fully of Mr. Elsden's work. So long ago as 1816 William Smith lamented that "the theory is in possession of one class of men, and the practice in another." This state of things is not wholly unknown at the present time, and if Mr. Elsden succeeds in his task of welding the two together, his labour will not have been in vain.

V.—Wachsmuth and Springer's Monograph on Crinoids.[1]

Fourth Notice.

THE Abactinal system of the Crinoid skeleton comprises the elements of the Stem and appendages, the Patina (in which are included only IBB, BB, and RR), and the dorsal ossicles of the Arms. Our authors' account of the two former has already been passed in review. Their description of the brachials (pp. 73–88) needs no elaborate discussion, since the controverted points were dealt with in an earlier notice. Let it be noted, however, that all abactinal elements beyond the five radials belong to the arms. Therefore, every normal crinoid has five arms. Each arm may remain single, or may fork once, or may fork an indefinite number of times, either regularly or irregularly. The branches into which it forks may be of equal or of very unequal size. The proximal regions of the arms may be incorporated with the patina to form the dorsal cup. The portion so incorporated is said to be 'fixed'; the remaining distal portion is termed 'free.' If only the primibrachs of an arm be fixed, then the secundibrachs will be free, and it will appear as though two arms left the calyx in that ray. If the secundibrachs be fixed, and the tertibrachs free and equally developed, then there will appear four free arms in the ray. But to say that the former crinoid has actually two arms to the ray, i.e. ten arms altogether; or that the latter has twenty arms—such statements breed confusion. Yet they are constantly made, and they are to be found in the present Monograph. A crinoid may have almost any number of arms (*Tetracrinus* has

[1] The North American Crinoidea Camerata. By C. Wachsmuth and F. Springer. Mem. Mus. Comp. Zool. Harvard, vols. xx and xxi, containing 838 pp. and 83 plates. (Cambridge, U.S.A., May, 1897.) For First, Second, and Third Notices, see June, July, and September Numbers.

four, *Promachocrinus* ten, and *Catillocrinus* about fifty), but it is not in this sense that Wachsmuth and Springer say that *Technocrinus spinulosus* has "arms twenty," or *Batocrinus quasillus* "arms twenty-two to twenty-four." This confusion would be avoided by using such a word as *ramus* for the main free branches of an arm. In that case the armlets borne by a ramus might conveniently be called *ramuli*.

The account of the arms is remarkably full, and contains many details not to be found elsewhere. Two conclusions of wider interest are arrived at. First, that "the number of costals [i.e. IBr] does not constitute a reliable character for classification, as heretofore supposed, and that in some groups their number is of but little value for specific distinction. This is even more markedly the case with regard to the higher divisions of the rays." The second conclusion is that the fixed brachials of the Camerata "were free in the early larva," "that smaller specimens have a less number of interbrachial plates, that the number increases with the size of the specimens, and that with the increase of the latter additional brachials are incorporated into the calyx." These two conclusions should win ready acceptance by students of Crinoidea. The second is of high importance, for it carries with it the further conclusion that the Camerata were descended from ancestors of Inadunate type, that is, forms with the arms free and distinct, and with the dorsal cup confined to the patina. In other words, if the statement be accepted, it becomes impossible for us to regard such a genus as *Reteocrinus*, and still more *Melocrinus*, as truly primitive; it is not open to us to suppose that any branch of the crinoids was derived from those Cystidea that have a large number of thecal plates; on the contrary, all the cystidean ancestors of the crinoids must be sought among forms that have their thecal plates limited in number and definite in arrangement.

We pass now to the plates of the Actinal system (pp. 88–104). Of these the most important are the Orals. At once we are faced by the question: what are the orals? The only definition that does not admit of controversy appears to be this: The orals are five subtriangular plates early developed in the interradii around the peristome of the stalked larva of *Antedon*, but reabsorbed in the adult—and all plates in other crinoids homologous with those five. The disputed point of this definition lies in its application. What plates are homologous? A full account of the various homologies that have from time to time been maintained by Wachsmuth and Springer and by other writers is given in the Monograph. Additional discoveries have rendered many of these homologies untenable, and what our authors now hold is as follows.

The orals are represented in *Haplocrinus*, *Pisocrinus*, *Symbathocrinus*, *Allagecrinus*, and allied genera (= Larviformia, W. & Sp.) by five subtriangular interradial plates, occupying the whole of the actinal surface, and meeting by their apices around the oral centre. This homology will scarcely find a hostile critic. Five plates similarly situated in the living *Rhizocrinus*, *Hyocrinus*, and *Holopus* have always been accepted as orals.

In a unique specimen of *Taxocrinus intermedius*, described b Wachsmuth and Springer in 1889, there are interradially dispose around the open mouth "five rounded or very obtusely polygona plates rather oval in outline," the posterior of these being "nearl three times as large as any of the others"; the food-grooves pass t the mouth between these plates, which "represent morphologicall the five orals of the recent genera." In the absence of furthe evidence, we may accept this conclusion provisionally, and we ma infer that such was the structure of the tegmen in allied gener (viz. in Flexibilia Impinnata).

In *Coccocrinus* and *Culicocrinus*, which are regarded as primitiv forms of the 'non-typical Camerata' (i.e. Platycrinoidea), the greate part of the tegmen is occupied by five interradially disposed plate which, very naturally, are taken to be orals. In those Platycrinoide which have a more complicated tegmen, these five plates can still b recognized; but in many species the posterior oral has been shifte towards the oral centre by the development of the anal tube behin it, and has increased in size while becoming partly surrounded by th four remaining orals. In other words, the so-called 'central plate of the *Platycrinus* tegmen is homologized with the posterior ora while the four so-called 'proximals' are homologized with th antero-lateral and postero-lateral orals. There seems no reason t doubt the justice of this conclusion. Turning to the 'typica section' of the Camerata, we find a similar 'central plate' an 'proximals' developed in many genera, as well exemplified i *Actinocrinus*; comparison of these with the structures alread described "leaves no room for doubt that these are likewise tru orals." Here, however, a conscientious critic is bound to point ou that external similarity between structures in highly specialize genera is often deceptive and, in the absence of genetic affinity or a plain evolutionary series, cannot be regarded as proof of homology With such splendid material in their hands, it is a pity that Messrs Wachsmuth and Springer did not attempt the solution of the proble by a method more satisfactory than that of simple inspection. Th task remains for others. It may, however, be conceded that th Camerate tegmen contains no other plates capable of bein homologized with the orals.

There remain for consideration various Inadunate gener (Fistulata, W. & Sp.) of which *Cyathocrinus* is taken b Wachsmuth and Springer as the type. In this genus are tw distinct sets of plates on the actinal surface, either set conceivabl as homologous with orals. There are five subtriangular plate (deltoids, F. A. B.) resting on the shoulders of the radials surrounding the pentagonal peristome, and meeting by their side underneath the food-grooves; the posterior of these is the largest and is pierced by water-pores. Again, there are in some individual five plates (proximals they may be called) interradially disposed and covering over the peristome; these plates are continuous wit the ambulacrals, often are barely distinguishable therefrom, and ofte appear absent; these plates and the ambulacrals, as well as an minute supplementary plates that may be developed in the tegmen

all lie above the level of the deltoids, which may thus be almost entirely obscured. Where the covering-plates, especially the five proximals, are well developed and preserved the deltoids are scarcely to be detected; but where they are small the deltoids are often conspicuous. Hence these two distinct sets of plates have occasionally been confused. That they are absolutely different morphological elements there can, thanks chiefly to the researches of Wachsmuth and Springer, be no doubt. The question is: which set represents the orals? Wachsmuth and Springer believe that the orals are represented by the proximals, but that these are often resorbed, much as we know the orals to be resorbed in the ontogeny of *Antedon*. They believe that forms with large proximals and hidden deltoids are, phylogenetically, less advanced than those with minute proximals and conspicuous deltoids. *Euspirocrinus*, for instance, is more advanced than *Cyathocrinus*. Neumayr appears to have believed that the deltoids were the orals and that the proximals were modified ambulacrals. Unfortunately, reliance upon the drawings of other authors led him to confuse the two sets in some instances, so that his views were thought more unsound than was really the case.

For many years I have devoted considerable attention to this matter, and have long believed the deltoids to be homologous with the orals, and the proximals, when they exist, to be enlarged ambulacrals. So great, however, was the opposition to this view on the part of my departed friends, P. H. Carpenter and Charles Wachsmuth, that in my published writings I always left the question open and continued to amass evidence. I believe myself to be now in a position to prove both these homologies definitely and step by step. That, however, must be done in another place with the help of adequate illustration. Here it is enough to point out the great difficulty of explaining the deltoids on any other hypothesis (see p. 115 of the Monograph); also, one may draw attention to the fact that the posterior deltoid and the posterior oral stand in similar relations to the water-vascular system.

The remaining elements of the tegmen are next discussed, and a full history of the various opinions that have been held is given. There are no new facts of importance, and no modification of the views published by Wachsmuth and Springer in 1891, and abstracted in the Geological Magazine for May of that year. Details, however, are filled in, and this section with its accompanying illustrations should be carefully studied.

Following on this come some very controversial matters. The ventral sac of the Fistulata "must not," we are told on p. 114, "be confounded with the anal tube of the Camerata, which contains simply the rectum." On the contrary, it "lodged a large portion of the visceral mass," and "is generally composed of longitudinal rows of hexagonal plates, which are often pitted at their sides, or perforated by pores." These pores are supposed to have admitted water for respiratory purposes. Messrs. Wachsmuth and Springer seem to think it curious (p. 161) that in my earlier writings on crinoids I should have regarded this supposed structure "as an excellent

ordinal character," whereas it is omitted altogether in my classification of 1893. At first I accepted the statement of these learned authorities, but when fact after fact showed that it was far from a universal truth, it was impossible to utilize it for classification. The anal tube of *Euspirocrinus spiralis* is as solid as that of *Actinocrinus*; that of *Cyathocrinus visbycensis* is but little less so; that of *C. ramosus* is a mere knob, and its lumen is quite small. Again, genera, species, and actual specimens that had been stated to possess pores and slits in the tube or sac were definitely proved by me to have nothing but deep folds. Wachsmuth and Springer now admit my statement for "*Cyathocrinus*, *Euspirocrinus*, and possibly the Cyathocrinidæ generally, in which very likely the madreporite performed the functions of the tube-pores"; but they "have the most complete evidence that among the Poteriocrinidæ, in many cases, the pores pass through the test." Perhaps they have. And yet I am still sceptical. It was examination of *Scaphiocrinus multiplex* itself, the first and chief species in which such pores were observed, that made me doubt the observation. I have examined, with like result, specimens described and figured by Grenfell and by Lovén. Now, let the impartial reader compare my detailed descriptions and the drawings by Liljevall, Hollick, and myself, magnified 8, 16, and 20 diameters, with the bald statements and drawings, scarcely more than natural size, published by Wachsmuth and Springer. He will admit that scepticism is justified. Nay, more! Let him examine two of the figures on which they specially rely, namely, pl. vii, figs. 5 and 9. He will observe that the supposed pores are drawn in the middle of each side of each hexagonal plate of the tube; each pore lies on a line passing between the centres of adjacent hexagonal plates. Then let him look at the other figures, such as 2*b*, and he will note that the supposed pores are at the angles of the plates, and never on these radial lines. Let him then examine a few hundred specimens of Fistulate genera, and he will find that the apparent pores or slits never are on the radial lines, but always at the angles or between the ridges of the folded plates. Some resemblance to the alleged structure of *Aulocrinus* is presented by *Gissocrinus verrucosus*,[1] but this is only partial and superficial. I do not accuse the authors of any intention to mislead, but this I do suggest: that their artist would not have drawn figures 5 and 9 in this way had he not been told to put in structures which he really had a difficulty in seeing. Few scientific writers have not had a like unfortunate experience. If *Aulocrinus* truly has a ventral sac of this nature, it differs far more from other Fistulata than Messrs. Wachsmuth and Springer have stated. If the structure is correctly drawn it is most extraordinary that it should not be specially mentioned in the text. But it is so opposed to all facts hitherto observed or published that, until Mr. Springer himself compares fig. 9 of pl. vii with the original specimen and assures us

[1] "Crinoidea of Gotland, I," pl. x, fig. 378: *Svensk. Vetensk. Akad. Handl.*, xxv, 2 (1893).

publicly that the pores have the position there assigned to them, and gives a properly enlarged drawing or photograph in support of his statement, scepticism will be more than justified.

F. A. Bather.

CORRESPONDENCE.

THE SUBMERGED PLATFORM OF WESTERN EUROPE.

Sir,—The question of whether the border of this platform is an escarpment or not cannot be left where Professor Hull leaves it, for, as it stands, one of us must certainly have a false idea of the meaning and use of the word *escarpment*. I am consequently obliged to refer Professor Hull to textbooks for a definition, and it will probably suffice if I quote the Student's Manual of Geology, by Jukes & Geikie (3rd edition, p. 474): "An escarpment is a cliff or precipitous bank formed by the outcrop of a bed or series of beds of harder consistency than those on which they rest."

Professor Hull asserts that the question "is really one of form" or shape of the ground, and he implies that the submerged declivity is an escarpment because it "has a terraced upper surface, has a descent sometimes almost precipitous, and falls off in a slope, sometimes gentle, at its base into the abyssal plain." Then he proceeds to put geological structure aside, which is precisely what the definition of an escarpment forbids him to do. It is quite true that the height and length of a declivity are matters of degree, but if he cannot show that a given declivity is formed by the outcrop of one series of beds he has no right to call it an escarpment.

Professor Hull, however, has another argument: he says, "the question of the origin of the escarpment might have remained problematical," but for the existence of the river channels which cross the platform and open out through the "escarpment." He regards these channels as being "unquestionable proof of subaerial origin, both of themselves and of the physical features with which they are connected." This is a novel argument certainly, but how the existence of river-made valleys can possibly prove the declivity to have been made by subaerial agencies passes my comprehension.

Let us apply the argument to an existing terrestrial surface, and for choice let us take Portugal; then we have this syllogism:—The surface of Portugal is trenched by river-valleys which open through the cliffs that form the western border of the land; such valleys prove all the physical features with which they are connected to be of subaerial origin; therefore the sea-cliffs of Portugal are "escarpments" of subaerial origin!

No one wants to deny that the surface of the platform has once been a land-surface, but I do deny that its border can properly be called an *escarpment* or that there is any proof of its having been fashioned by subaerial agencies.

A. J. Jukes-Browne.

ORTHITE.

Sir,—In the interesting and instructive paper on Scottish Rocks containing Orthite, communicated by Dr. Flett to the September number of the Geological Magazine, the author states that the